Vol. XXVII | PSYCHOLOGICAL REVIEW PUBLICATIONS | Whole No. 118 1919

Psychological Monographs

PSYCHOLOGICAL STUDIES FROM THE CATHOLIC UNIVERSITY OF AMERICA

EDITED BY
EDWARD A. PACE
Professor of Philosophy

2

A Study and Analysis of the Conditioned Reflex

BY
IGNATIUS A. HAMEL, A.M.

PSYCHOLOGICAL REVIEW COMPANY
PRINCETON, N. J.
AND LANCASTER, PA.
Agents: G. E. STECHERT & CO., London (2 Star Yard, Carey St., W. C.)
Paris (16 Rue de Condé)

PREFACE

The advent of the conditioned reflex into the field of psychology has suggested a study and analysis of this interesting phenomenon. This monograph is intended to present the results and conclusions of such an experimental investigation. The work was performed in the psychological laboratory of the Catholic University of America during the years 1916-17 and 1917-18.

The sources used are indicated in the section on bibliography and in the footnotes. Besides the material available in the University Library, the writer made use of the Library of Congress and the Surgeon General's Library—particularly the latter. The author's chief acknowledgments are due the Knights of Columbus, whose fellowship foundation at this university made his graduate work possible; to Dr. Thomas V. Moore, of the Department of Psychology, with whose valuable help and assistance the work was begun and completed; to Dr. Pace, for suggestions and criticisms on the draft of the manuscript; and to all those who so kindly acted as subjects in these experiments.

IGNATIUS A. HAMEL.

Washington, D. C.,
March 15, 1918.

TABLE OF CONTENTS

INTRODUCTION

The concept of the conditioned reflex is based upon the principle that if two stimuli, one of which is the definite stimulus to any reflex action and the other any indifferent stimulus to this reaction, are administered jointly and many times under the same conditions, the latter (the indifferent or *negative* stimulus) will eventually be grafted on to the ordinary positive stimulus which produces the usual reflex act, i. e., the indifferent stimulus will gradually become the stimulus to a reflex action, even when the usual stimulus to this reflex is not present. For example, if an electric shock, a definite stimulus, which produces a direct reflex withdrawal when applied, e. g., to the finger, and any indifferent stimulus to this particular reaction, such as the sounding of a bell or a flash of light, are administered jointly several times, the usual reflex (to the shock) will finally, after many joint applications of the stimuli, be produced by the sound of the bell or the flash of light alone. Such a reaction is called a conditioned reflex—a "reflex" act *conditioned* by the repeated application of two stimuli such as, for instance, the above mentioned.

Earlier publications of the work done in Pavlow's laboratory upon secretion in the dog have shown the production of a conditioned salivary reflex. That is, if food or some other similar salivating agent which produces a direct salivary reflex, and, e. g., a flash of light are offered jointly for a number of times, the light alone will come finally to call out the salivary reflex. The history of the development of this so-called reflex will help to a better understanding of the problem at hand.

HISTORY OF THE PROBLEM

The conditioned reflex owes its development to the rather extensive and comprehensive study of glandular reaction, especially that of the salivary glands. Therefore, in order to trace its development properly, one must review the various problems under-

taken in the study of secretion, especially those investigations in which the secretion is looked upon as being of a reflex nature. Early investigators of secretory reaction discovered that secretion was not due entirely to the direct stimulation of the glands, but that other factors entered into the field which produced the flow. In 1833 Mitscherlich studied the salivary reaction in a man forty years old.[1] His observation was made possible by a fistula in the left Stenson's duct. He found a considerable variation in the flow of the saliva at different times. During sleep the gland produced 0.09 cc. of saliva per hour; during quiet reading (with movements of the mouth) it produced from 0.41 to 0.53 cc. per minute; and during meals from 0.8 to 2.00 cc. per minute. He concluded that the amount of secretion appeared to be proportioned to the degree of activity of the subject. It is interesting here to note that he mentioned the psychic effect of *taste,* as he found a greater secretion to *tasteful* than to *tasteless* foods. In 1854-56 Colin recognized the effects of chewing upon salivary secretion.[2] But he offered the suggestion that it was effective because it reduced the size of the food particles and so allowed a more ready stimulation of *taste.* He also noted that chewing on one side produced a greater stimulation on that side than on the other. In 1860 Ordenstein observed the rate of secretion in a small boy for 24 hours.[3] He studied this by means of a cannula attached to the gland. He found (contrary to Mitscherlich) very little variation in the flow of saliva except when food is taken in. He also reported secretory reactions to the direct stimulation of the walls of the Stenson's duct. He was not successful in an attempt to establish a correlation in amount of secretion with different diets—vegetable, mixed and meat diet. Ordenstein criticized the use of the cannula as a means of observing the salivary flow. The method is not valuable, according to him,

[1] Mitscherlich, C. G. "Ueber den Speichel des Menschen." Poggendorff's "Annalen d. Phys. u. Chemie," 1833. 27. pp. 320-345.:

[2] Colin, G. "Traité de physiologie comparée des animaux domestiques." Paris-Baillere, 1854-56. Reported by Lashley, S. K.

[3] Ordenstein, L. "Ueber den Parotidenspeichel des Menschen." Beitr. z. Anat. u. Physiol. 1860. 2. (103-122).

since leakage around the cannula may occur and also because of the difficulty of keeping the cannula in place. In 1863 Eckhard[4], by means of a cannula, inserted into the ducts of the larger glands collected secretory fluid, but he studied its chemical properties rather than the reflex excitability of the glands. In 1864 Oehl[5] determined the rate of secretion of the submaxillary gland in two normal humans to be from 6.00 to 7.12 grams per hour. He also criticized the use of the cannula. However, the reflex excitation of the gland due to the presence of the cannula was not mentioned in the criticism of either Ordenstein or Oehl. In 1875 Lepine[6] and Bochefontaine observed that by stimulating certain areas of the brain they produced secretion of the maxillary glands (in the dog). This was later confirmed by Bechterew (1889), Bary (1899), Belitzki (1906), and Spirton (1909), reported by Babkin.[7] In 1876 Tuczek[8] measured the quantity of salivary secretion by means of a unique though inaccurate method. He fed his subject dried food. He then measured the increase of this in weight, thus obtaining the total secretion. After experimenting with a great variety of foods, he concluded that the secretion varied inversely as the water-content of the food. He also agreed with the previous investigators that the secretion was influenced by the factor of *taste*. He found a relation between the total secretion of saliva secreted and the age and sex of his subjects, women and children giving less secretion than men.

In 1878 Pawlow[9] first opened the road to a broader study of glandular secretion. He found an inhibition in secretion when drawing out the folds of the intestine of the dog (he concen-

[4] Eckhard, C. "Ueber die Eigenschaften des Sekretes." Beitr. z. Anat. u. Physiol. 1863-3. p. 39-50.

[5] Oehl, E. "La Saliva umana studiata colla siringazione dei condotti gliandolari." Pavia, Fusi. 1864. (Reported by Lashley.)

[6] Lepine, and Bochefontaine "L'influence de l'excitation du cerveau sur la sécrétion salivaire." Gazette med. de Paris, 1875, p. 332.

[7] Babkin, B. P. "Die äussere Sekretion der Verdauungsdrüsen." Berlin, Springer, 1914, p. 71-73.

[8] Tuczek, F. "Ueber die vom Menschen während des Kauens abgesonderten Speichelmengen" Zsch. f. Biol. 1876, 12, 534-557.

[9] Pawlow, J. "Ueber die reflectoriche Hemmung." Arch. f. d. ges. Physiol. 16, p. 272-292, also reported by Lashley Psy. Rev. 1916.

trated his work upon the animal—the dog chiefly). He considered this inhibition to be what he termed the *excitation* of *reflex paths* from the region stimulated. His contribution to the physiology of gastric secretion is well known. He obtained a method of producing gastric secretion in a dog by feeding it a sham meal, in which the food was taken into the mouth, chewed, and when swallowed simply fell out of an opening in the neck and never reached the stomach. In Pawlow's original work he made no anthropomorphic interpretations, but later publications from his laboratory reveal interesting statements which we shall discuss later.

In 1899 Kuss[10] noted that chewing movements with empty mouth produced an increase in the rate of salivary secretion from 0.8 cc. to 20.0 cc. per hour. In 1904 Sellheim[11] observed a salivary flow (in dogs) produced by the sight and smell of food as well as by means of the gustatory stimulation of the same food. He found a correlation between the percentages of solid substances in the secretion produced by these two different stimuli of the same food.

In 1905 Zebrowsky[12] denied the effects of secretion by chewing with empty mouth. He also found little or no secretory action during rest. However, he agreed with the earlier investigation of Colin in claiming that the abundant secretion obtained by chewing tasteless objects was due to *tactual* stimulation. He found bread to be an effective stimulus if chewed, and not so effective if held quietly in the mouth. He, too, found that chewing on one side of the mouth produced a greater stimulation on that side than on the other side. The results of his investigation he formulated into the following laws: First, that the amount of secretion is proportional to the square roots of the intensity of the stimulus. Secondly, the stimulus influences chiefly the rapidity of the secretion; and thirdly, that the quantity and intensity of the stimulus influences chiefly the rapidity of the secretion.

[10] Kuss, G. "Notes sur la salive parotidienne de l'homme." J. de l'anatomie, 1899, 35, p. 246-53.

[11] Sellheim, Q. P. St. Petersburg, 1904, see Babkin, *op. cit.*, p. 71.

[12] Zebrowsky, E. V. "Zur Frage der secretorischen Funktion der Parotis beim Menschen." Arch. f. d. ges. Physiol. 1905, 110, pp. 105-173.

In 1909 Popielsky,[13] contrary to Zebrowsky, stated that the quantity of the secretion is proportional rather to the absolute quantity of the stimulating substance. He placed sand in the mouth of a dog and attributed the abundant secretion thus recorded to the penetration of the fine particles to the base of the papillae, where mechanical stimuli should be more effective.

Brunacci, in 1910,[14] found no secretory activity during rest. He tested the stimulating effect of water at different temperatures upon secretion. He found that temperatures above 60 degrees and below 15 degrees (Centigrade) had a slight excitatory effect, and he attributed the excitation observed to the pain receptors rather than those for temperature. He failed to distinguish between mechanical and other stimuli involved in chewing. The stimulation observed in chewing tasteless rubber he ascribed to mechanical stimulation, without further analysis. He first noted that swallowing movements produced secretion.

In 1911-12 Zeljony[15] reported that a reflex could be obtained (in the dog) by stimulating the salivary glands even when the cortex is removed; also when the cerebrum is separated from the medula oblongata by cross-section through the pons varolii. Therefore the arc of the salivary secretion-reflex runs somewhere beneath the cortex. However, it is interesting to note that in the animals whose cortex was removed, salivary secretion was only obtained by introduction into the mouth of certain substances. Sight, smell and sound were ineffective. Therefore the cortex is involved in the transmission of these stimuli.

In 1914 Brunacci and De Sanctis[16] were the first to regard

[13] Popielsky, L. "Ueber die Gesetze der Speicheldrüsen Tätigkeit." Arch. f. d. ges. Physiol. 1909, 127, pp. 443-473.

[14] Brunacci, B. "Sulle variazioni fisiologische della parotide nell' uomo. Nota, I, Arch. di fisiol., 1910, 8, pp. 421-427. Reported by K. S. Lashley.

[15] Zeljony, G. P. "Ein Hund ohne Grosshirnhemisphären." Verh. der Gesellsch. Russ. Aerzte zu St. Petersburg. 1911-12. Reported by B. P. Babkin, *op. cit.*, p. 72.

[16] Brunacci, B. e De Sanctis, T. "Sulla funzione secretoria della parotide nell' uomo. Nota II. Influenza inibitrice dell' attivita psichica sulla quantità e qualita della saliva secreta." Arch. di Fisiol., 1914, 12, pp. 441-454. (Reported by K. S. Lashley, Jr. of Exper. Psychol. 1916, pp. 486-487.

mental application in its effects upon secretion. They placed a small quantity of dilute acid in the subject's mouth each minute during the observation. This was applied while the subject was engaged in mental work, and at rest. They discovered that while the subject was mentally engaged there was a noticeable inhibition in the secretion of the parotid gland. Lashley's criticism of this we will take up later.

Pawlow[17] recognized the reactions involved by stimulating the oral mucosa directly, and those involved by sight, smell and sound which, as Zeljony observed, involved the cortex. He distinguished the two by saying that the first reflex is an inborn act; the second is acquired through experience. The secretion is extraordinarily constant in its physiological condition, when the sensory area of the mouth is stimulated; whereas the secretion in case of stimulation of other surfaces of receptive areas is less constant and subject to variation. Sometimes it is present, sometimes not. The first of these reactions Pawlow called the *unconditional* reflex, and the latter the *conditional* reflex. However, Bahkin sees no reason to classify them distinctly in the physiological sense as in both cases the central nervous system is involved.

From Pawlow's Huxley lecture[18] we learn that he strenuously objects to the psychical concept of the conditional reflex. He endeavors "to restore to physiology what properly belongs to it." He leaves to physiologists to examine the conditioned stimuli which were nothing more than "very complex mechanisms of accommodations" in order to arrive at an exact knowledge of the mechanism involved. This, he suggests, could be done in connection with the progressive and systematic derangement of the central nervous system.

In 1914 Morgulis[19] gave us a valuable insight into the work and theories of Pawlow. His work, covering a period of about ten years, consisted of an investigation of the function of the central nervous system by means of the conditioned reflex. He

[17] Reported by Babkin, B. P. "Die äussere Sekretion der Verdauungsdrüsen." Berlin, Springer, 1914, pp. 73.

[18] Pawlow, J. Lancet, 1916, Vol. CLXXI, p. 911 (translated).

[19] Morgulis, Jr. of animal Behavior. Vol. 4, 1914, pp. 362-379.

established many kinds of conditioned reflexes in animals. His work was almost exclusively on the conditioned salivary secretion, an important "reflex" development being that of a conditioned secretion to sound. Morgulis tells us that "a mass of material has accumulated which could easily fill a volume."[20] He defines the conditioned reflex as "A reaction to an indifferent stimulus, occasioned merely by a repeated coincidence of the latter with a physiologically active stimulus."[21] Concerning his theory and method, "His point of view is thoroughly materialistic, and his terminology and methodology alike are most consistently objective."[22] Pawlow regards the hemispheres as the seat of conditioned reflexes, just as the spinal cord is the seat of unconditioned, permanent, or inherent reflexes. In analyzing the formation of a conditioned reflex he claims that "any external factor acting upon an analyzer may be brought into temporary association with a definite physiological activity, as, for instance, the activity of the salivary gland. This association is brought about by repeatedly combining that factor with the physiological stimulus of the gland (food, acid). When, after a time, such a connection is formed, the particular factor which previously had no relation to the salivary gland now affects it as a stimulus."[23]

This "association," as Pawlow calls it, is explained physiologically in the development by means of two laws, viz., the law of radiation of nervous processes in the brain and, parallel to radiation, an opposite phenomenon called the law of concentration of nervous processes. The gradual concentration of the nervous process, with the resulting differentiation of the stimulus, is due to the development in the central nervous system of inhibitory processes. The finer the differentiation of the stimulus the more intense the inhibition. There are several forms of inhibition. One is sleep, which either diminishes or completely obliterates all conditioned reflexes. In the waking state, stimuli reaching the cortex come into competition with one another. "Every new

[20] *Op. cit.*, p. 363.
[21] *Op. cit.*, p. 363.
[22] *Op. cit.*, p. 362.
[23] *Op. cit.*, p. 363.

factor comes in collision with others already acting in the brain, and either draws to itself the available supply of energy or is crowded out by the more intense stimuli. In general terms, it means that a strongly irritated point in the central nervous system lowers the affectability of adjacent regions."[24]

"Psychic activity," according to Pawlow, plays no part. "This seemingly chaotic and infinitely complex, ever-changing reaction of the organism to the flux of countless influences of the outer world, in a word all that is commonly called psychic activity, is nothing but an endless chain of reflexes, i. e., determined responses to the environment. The kaleidoscope of conditioned reflexes, in its fantastic and apparently irregular and undefinable play, in reality is controlled by rigid laws, by the intensity, duration, and direction of the nervous processes in the large hemispheres."[25]

Consciousness and unconsciousness, according to Pawlow, are purely physiological phenomena, "a state of a part of the large hemispheres characterized by an optimum affectability."[26]

In 1914 Doutchef and Dezeuze[27] gave an elaborate interpretation of the process of association in conditioned secretion in terms of images and affective elements, which is vigorously attacked by Lashley,[28] who calls it "wholly unjustifiable."

In 1916 Gley and Mendelssohn[29] found it "difficult to conceive of the production of 'conditioned reflexes' without the intervention of psychic elements, phenomena of memory and associations, images, perhaps even simple judgments." They add: "It is probable that in so complex a reaction the individuality of the subject, especially in the human species, may play a great role." They tested a patient with a fistula in Stenson's duct, and obtained a slight secretion at the sight of food. However, there was no significant secretion at the thought of it. They also tried to

[24] *Op. cit.*, p. 371.
[25] *Op. cit.*, p. 373.
[26] *Op. cit.*, p. 375.
[27] "L'image et les réflexes conditionelles dans les travaux de Pavlov." Paris, 1914.
[28] Psychol. Rev., XXIII No. 6, pp. 446-464.
[29] "Quelques expériences sur la réflexe salivaire conditionelle chez l'homme." Compt. Rend. Soc. de Biol., Paris, 1915, LXXVIII, pp. 645-649.

establish a conditioned secretion to sound and light in the following way. Notes on a flute were sounded, or a bright light was flashed in the eyes of the subject. At the same time a small piece of chocolate was placed in the subject's mouth. This was repeated forty times, and they developed a secretion neither to the light alone nor to the flute alone. In this connection, it is our opinion that if this were repeated many more times these experimenters could easily have developed a secretion to their "negative" stimuli.

In 1916 Lashley[30] suggested that the continual salivary flow was due to the constant stimulation of the mucosa of the digestive tract. This, he claimed, may be reflex in nature. Regarding the excitatory effects of chewing: "My own experiments indicate that the secretion is fully as complex as many conditioned secretory reflexes and depends to a large extent upon previous visual and cutaneous stimuli." In regard to the variation in the quantity of the secretion he claims that it is not wholly due to the changes in the intensity of the stimulus, but that other factors are concerned, such as the area of the tongue stimulated (and palate as well); the duration of the stimulus; the rate of the dilution of the stimulating substance with saliva, and other valuables besides the concentration of the stimulating substance.[31]

In the same year Lashley[32] published an excellent piece of work upon the Reflex Secretion of the Human Parotid Gland." He observed the salivary flow by means of a specially constructed cannula, which was placed against the gland and held there by suction. He was unable to verify the results of Brunacci and De Sanctis. He claims that mental work involves movements of the tongue and throat which increases the secretion. They, on the other hand, held that distraction—e.g., mental work—inhibited the secretion.

Concerning the conditioned salivary reflex, it is interesting to note that in Lashley's earlier work he claimed to have obtained

[30] Lashley, K. S. "The Human Salivary Reflex and Its Use in Psychology." Psy. Rev., XXIII, No. 6. pp. 446-464.

[31] *Op. cit.*

[32] Lashley, K. S. "Reflex Secretion of the Human Parotid Gland." Jr. of Exper. Psy., Vol. I, No. 6, 1916, pp. 461-492.

no evidence for them in man. "Man analyzes the experimental situation and cannot be deceived into expecting food, as the dog is under similar conditions."[33] But in his later work he reports their development.[34]

After having his subjects abstain from food for twenty-four hours, the cannula and drainage tube were fastened over the left Stenson's duct and the subject was shown a great variety of foods. He found no increase in secretion following the sight of the food. After allowing the subject to eat a single raw oyster, however, he noted an immediate change in the salivary reaction to the sight of the food. He also observed that, "Where no secretion was excited by the sight of food, raising the food toward the mouth was sufficient to excite secretion, except in the case of the peppermint, which the subject dislikes."[35]

He was also successful in exciting secretion to the odor of food. He analyzes these reactions as being *conditioned* by hunger, *previous experience,* and also by complex *emotional* factors.

He came to the following conclusions, in all of his experiments:

"1. Direct reflexes of the parotid gland are excited by mechanical, chemical, and protopathic stimulation of the oral mucosa. Lack of an adequate method of limiting the distribution of chemical stimuli has prevented accurate quantitative experiments.

2. There is probably no direct reflex to thermal stimuli unless they are of protopathic intensity.

3. The secretion produced when a foreign object is chewed involves a specific reaction to a complex group of stimuli.

4. The reaction of the parotid is most intense when the homolateral mucosa is stimulated.

5. The quantity of secretion varies with different chemical stimuli applied to different parts of the mucosa, but is usually greatest when the proximal region of the tongue is stimulated.

6. The presence of food in the stomach excites secretion.

7. There is no direct reflex to olfactory or to ordinary visual, auditory, or tactual stimulation.

8. Parotid secretion is partially inhibited by violent muscular

[33] *Op. cit.*
[34] *Op. cit.*, p. 489-491
[35] *Op. cit.*, p. 490.

activity. Mental work (involving movements of the tongue and throat) increases the secretion.

9. Erotic emotion reduces the quantity of secretion.

10. Reflex secretion is excited by the sight and odor of food, but is conditioned by hunger, by the previous experience of getting food under the conditions of the experiment, and by complex emotional factors which have not been analyzed."[36]

The Conditioned Motor Reflex

The work of Pawlow and his assistants prompted a movement on the part of his students to undertake the development of conditioned reflexes in man. Thus, we find Bechterew[37] bringing to our notice a simple way of producing a conditioned motor reflex. He had his subject sit with his foot resting upon two electrodes. He then applied a sound stimulus together with a strong electrotactual stimulus. A faradic current was used. The subject when shocked would jerk up his foot and the experimenter recorded the movement. After several joint applications of the two stimuli he soon developed the "reflex" withdrawal of the foot to the sound alone.

Watson, who four years ago condemned the methods of modern psychology and has since been trying to find a substitute for introspection, enthusiastically hails the conditioned reflex as the key which will open the gates to new methods of investigating problems which have hitherto been open only to introspective methods.[38]

He developed conditioned motor reflexes by the Bechterew method. However, instead of the foot movements, he worked upon the finger reaction. The subject placed the palm of the hand upon a brass electrode, and the middle finger of that hand was placed in contact with the second electrode. By means of tambours (attached to the finger electrode, and one in contact with a revolving smoked drum) he obtained graphic records of the movements of the finger. By means of a series of switches

[36] *Op. cit.*, pp. 491-492.

[37] Reported by J. B. Watson, "The place of the conditioned reflex in psychology." Psy. Rev., 1916, XXIII No. 2, pp. 94-96.

[38] Watson, J. B., *op. cit.*, pp. 89-116.

the experimenter (who was in an adjoining room from the subject) could give at will the bell stimulus, the shock, or both coincidentally. The bell and shock were given simultaneously for about five trials; then the bell was given alone. If the reaction did not appear (to the bell alone) the bell and shock were again given together a number of times. Then the bell was again offered. The reaction to the bell alone was found to make its appearance at first haltingly, i. e. it appeared and then disappeared. Punishment was then given (the shock). It was next found to appear twice in succession and again disappear. After a time, however, it appeared regularly every time the bell was offered. He found that in his best cases he was able to get a conditioned reflex after fourteen to thirty combined stimulations.

Watson also obtained the respiratory curve by means of a tambour connected with a pneumograph, and, aided by their readings, he observed that the conditioned motor reflexes obtained were at first usually sharp, quick, and widespread, the whole body as a rule being brought into the reaction. He also noted, with regard to their persistence, that when once thoroughly established they could easily be recalled the next day. In one instance, after five months the reflex reappeared in a subject after a single administration of the combined stimuli.

He attempted to establish the reflex to the pupillary reflex and the heart-beat, but these two methods he found to be unsatisfactory. He easily obtained the motor reflex in a dog. He stimulated the sole of the foot, and recorded the resulting leg movement. In six out of seven chickens he shows the conditioned reflex in the respiratory curve.

Regarding the applicability of the method, he says: "The method gives us the possibility of objectively approaching many of the problems in sensory psychology. We give no more instruction to our human subjects than we give to our animal subjects. Nor do we care what language our subject speaks, or whether he speaks at all. We are thus enabled to tap certain reservoirs which have hitherto been tapped only by the introspective method. The data which we collect in this way, while

they have no bearing upon a Wundtian type of psychology, serve (as far as they go) every practical and scientific need of a truly functional psychology."

Watson asked his subjects no questions at all. That he should not do so was demanded by his problem, viz., to find a substitute for introspection and to get along without an appeal to consciousness. He wished to show the possibility of getting results from human subjects by the methods of animal psychology. All questioning and demands for introspections were, therefore, excluded by the very technique of his procedure. The conditions under which he was working had, however, a certain disadvantage. Much could have been learned about his subject's mode of procedure by a little questioning after their reflex was developed. This information which escaped him because he neglected to make any use of introspection, would really—as we shall see later—throw no little light on the nature of the conditioned reflex.

The Conditioned Reflex Compared with Other Reactions

The question now arises, are the phenomena called conditioned reflexes properly designated by the term *reflex?* Some authors maintain, as we have seen, that the "conditioned reflex" depends upon consciousness. Pawlow says that it is a cortical reflex rather than a spinal one; but at the same time he attempts to get along without any appeal to consciousness. It has been a more or less tacit assumption that conscious phenomena are cortical. Now if it has been shown that the "conditioned reflex" demands the cooperation of the cortex, one who recognizes consciousness at all may be inclined to suspect that the designation *reflex* is inapt, because heretofore reflexes were supposed to exclude any dependence on consciousness.

To clarify the situation, it may be well to distinguish clearly certain phenomena which, while they have points of resemblance, are nevertheless very different when we look at their intimate mechanism. Let us therefore examine a little more closely the phenomena, which may be classified as (a) the reflex act, (b) the response of an organism to a situation, and (c) the conditioned reflex.

(a) The Reflex Act

The simple reflex is distinguished from the more complex reactions of the organism by the fact that it is not mediated by consciousness, the paths of nervous conduction being wholly below the cortex and its reaction-time being relatively short. An example of this is the winking reflex which Dodge and Benedict have recently shown to vary from 0.030 to 4.040 seconds in normal human subjects.[1] On the other hand, in man at least, the reactions of an organism may be mediated by what we term consciousness. The paths of nervous conduction involve the cortex and the reaction-time is therefore relatively longer.

But we know from neurology that the simplest reflex could not involve less than two neurons. As the number of neurons involved varies with the intensity of the stimulus, so the organism is accordingly more or less involved, or, in other words, the nervous impulse somewhere in its course comes into relation with other reflex paths, and in this way variations in the response are produced.

Neurologists picture the reflex act as affecting an organism whose nervous system is in a state of what is often termed neural tension. The stimulus disturbs the equilibrium at a certain point (the receptor), and the wave of nervous impulse thus set up irradiates through the complex lines determined by the neural connections of the receptor. "If the stimulus is weak and the reflex path is simple and well insulated a simple response may follow immediately. Under other conditions the nervous discharge may be inhibited before it reaches any affector, or it may irradiate widely, producing a very complex reflex pattern. In the former case the neural equilibrium will be only locally disturbed, and in the latter case almost the whole nervous system may participate in the reaction."[2]

Thus, from the neurological point of view we find the "complex" reflexes differing from the simple reflexes only in complexity, i. e., depending upon the strength of the stimulus and upon the condition of the neural paths.

[1] Carnegie Publications, 1915, Washington, D. C., pp. 36-46.
[2] Herrick, C. J. "An Introduction to Neurology," 1916, p. 66.

On the other hand, psychology would draw a hard and fast distinction by considering the reflex primarily as a physiological, not a psychological, fact. Its dependence rests not on consciousness but on a stimulus affecting the nervous system. The contraction and dilation of the pupil of the eye, the movements of the decerebrated frog, the movements belonging to the ordinary and normal routine of the vegetative life of the organism—heart-beat, contraction and dilation of the blood-vessels, breathing, swallowing, secretion of saliva, etc. are pointed out as movements of a purely reflex character almost wholly physiological, and movements which are not dependent on an act of consciousness. Here it is well to distinguish between movements within the organism involving the autonomic nervous system and those of the organism involving the central nervous system.

Unfortunately, we do not know as much about the autonomic nervous system as we do about the central nervous system, but we do know that the child comes into the world endowed with a mechanism of neural action involving muscular movements. Respiration, circulation, and digestion are carried on from the very first. These are, to be sure, primarily physiological. But immediately the child is thrown into the world of experience. Its first movements are random and rather spontaneous, but it soon acquires the power of muscular co-ordination. Every co-ordination which it is successful in accomplishing requires the child's immediate attention to that particular function. Gradually, as the new co-ordination becomes more firmly established, less attention needs to be paid to reproduce it until finally it is performed almost automatically. We experience the same fundamental process in perfecting any new co-ordination in adult life. The so-called reflexes thus established through experience are therefore different, in their origin at least, from those almost wholly physiological functions which we have from birth. In fact, looking at it in this light we find it extremely difficult to draw the hard and fast line of distinction between the "non-conscious" and the "conscious" reflexes, as they would appear to run in an ascending plane, as it were, from complexity to simplicity.

Furthermore, Herrick and Coghill, in their studies on the development of the nervous system of Amphibia, have shown that the first reflex circuits to come to maturity are made up of rather complex chains of neurons, so arranged as to permit of only one type of response, namely a total reaction (the swimming movement) from all possible forms of stimulation, and that in successive later stages this generalized type is gradually replaced by a series of special reflexes involving more diversified movements.[3] Parallel with this process, the higher correlation centers are developed for the integration of the several special reflexes into complex action systems. The simplest reflex arc (involving two neurons) is the final stage in this developmental process, whose initial stages are much more complex and diffuse arrangements of neurons adapted for total reactions of a more general sort.

Moreover, neurologists agree that in the higher vertebrates the simplest possible mechanism, involving only two neurons, probably never occurs, but that it is merely one element of a more complex reaction involving more neurons together with more centers. The concept of a reflex action, therefore, involving simply "stimulus and response" does not appear to be sufficiently comprehensive. The very important element—the connecting medium—is not taken into consideration at all by this purely objective interpretation.

(b) Responses of the Organism

Not all the responses of the organism are as simple as the reaction of the iris to light or the kick of the knee when it is struck by a hammer. Thus, for instance, when one is thirsty he goes to get a drink of water. The movements here involved are responses to the feeling of thirst, but they are conditioned by far more complicated processes than those which determine the movements of a simple reflex. We may term these *responses of the organism,* to distinguish them from the simple reflexes. These responses of the organism reveal themselves to one's inner experience as dependent on consciousness, and thus differ from the simpler reactions inasmuch as the movement of a simple reflex

[3] Herrick, C. Judson, and Coghill, G. E., 1915. "The Development of Reflex Mechanism in Amblystoma," Jour. Comp. Neur. Vol. XXV, pp. 65-85.

does not take place in conscious dependence on incoming sensations. Simpler than such responses of the organism are the prearranged reactions to stimuli, such as are studied in "reaction-time" experiments. There have not been wanting some who looked upon the quickest of these reactions as genuine simple reflexes, of similar nature, i. e., to the knee jerk, etc.

Thus Cattell[4] analyzes the reaction as follows: "(1) The stimulus is converted into a nervous impulse; (2) the nervous impulse travels along the sensory nerve and, it may be, the spinal cord to the brain; (3) through sensory tracts of the brain to a sensory center; (4) changes occur in this center; (5) these changes are followed by a discharge from a motor center; (6) the motor impulse travels along motor tracts in the brain; (7) along the motor nerve and, it may be, the spinal cord; and finally, (8) the muscle is innervated. The process is probably an acquired cerebral reflex, not accompanied by consciousness." The "muscular" reactions to which Cattell here refers may possibly approach the simple conditions of a reflex mechanism, but it is more likely that they are not identical with simple reflexes.

There was no doubt, however, among the older psychologists that the sensorial reaction and compound reactions, with their much longer reaction-times, were dependent on an act of consciousness.

Wundt thus analyzed the reaction time which, according to him, is made up of the five following processes: "(1) Conduction from the organ of sense to the brain; (2) Entrance into the field of consciousness; (3) Entrance into the focal point of consciousness; (4) The stimulation of the will, which sets free the motion registered in the central organ; and (5) Conduction of the motor discharge thus arisen to the muscles and the increase of energy in them."[5] This analysis Wundt looks upon as that of a complete reaction, and he calls it *sensory*. A shortened form of reaction takes place, however, when the attention is focused upon the reacting organ, and, according to Wundt, this corresponds to the analysis given by Cattell.

[4] Cattell: National Academy of Sciences, Vol. VII, pp. 393-394, cited from T. V. Moore, Reaction Time and Movement, Washington, D. C., 1904, p. 2.

[5] "Grundriss der Psychologie" Leipzig, 1893, p. 421.

It would be useless for our purpose to attempt here a review of all the work done on reaction time. However, we present later a table showing the reaction times observed by some investigators on some of the important reactions.

Baldwin's analysis of the reactive consciousness into (1) the receiving consciousness (the stimulus); (2) the attention involuntarily drawn (the registering element); and (3) the muscular reaction, is criticized by Dewey, who claims that the status prior to that of the reception of the stimulus into consciousness should be taken into consideration.[6] "The stimulus is not absolutely ex abrupto from the outside, but is simply a shifting of the focus of emphasis, a redistribution of tensions within the former act."[7] So the prior activity influences the value of the stimulating sensation. Dewey would call each state a sensori-motor co-ordination of the state prior to it, and this in itself he would call an act—"a sensori-motor co-ordination, which stimulates the response, itself in turn sensori-motor."[8]

In fact, we have something more to deal with here than receptor, center, and effector. The psychologist, looking at it from the point of view of development in the individual, or from that of the analysis of the mature consciousness certainly conceives something far more comprehensive than that conception which interprets the reactive consciousness by means of the concept of the reflex-arc.

(c) The Conditioned Reflex

Does the conditioned reflex belong to the class of phenomena called reflexes, or does it depend, as Gley and Mendelssohn suggest, on psychic factors, which would necessitate its being taken out of the class of reflexes and placed among the more complicated responses of the organism?

The originators of this concept regard it as a kind of secondary arc of response which has been grafted on a primary arc by asso-

[6] Dewey, John; "The reflex-arc concept in psychology." Psychol. Review, 1896, Vol. III, No. 4, p. 361.

[7] *Ibidem.*

[8] *Ibidem*, p. 366.

ciation of two stimuli. The first stimulus reflexly leads to a given response; the second does not. By dint of frequent reptition of the two stimuli a neural pathway is finally formed between the second stimulus and the response. In this way of considering the conditioned reflex it would seem to be properly designated as a reflex and to have the right to be included among the class of reflex actions. Consciousness does not play an effective part in the production of a reflex movement. It may or may not arise subsequently—as, for instance, one may notice that his eye winks without the winking being dependent on the conscious perception of the stimulus to which the winking is a response. Or his eye may wink without his being even aware of it, because of interest in other matters. The question now arises, whether or not the conditioned reflex does arise in this purely mechanical way, or whether some other concept of its mode of production is possible—or even perhaps, more probable. Does consciousness enter in as a factor? Does the fact that some observers have felt that it must be a "cortical reflex" suggest the possibility that it is not a reflex at all—that its development does not depend upon the mere neural association of two stimuli, but upon an actual conscious event which initiates the movement of response? At all events, the suggestion of Gley and Mendelssohn is not to be discarded without a careful weighing of the pros and cons for the two ways of interpreting the phenomena which have fallen under the term "conditioned reflex."

This may seem to some a mere question of words, but the problem is more than one of terminology. The cardinal point is not what we shall call the conditioned reflex, but, rather, what is its intimate nature. Allied to this problem is one of still greater importance: whether or not the psychologist can get along without consciousness, and whether the conditioned reflex is the means by which this will be made possible.

Watson has made the claim that by means of the conditioned reflex we are "enabled to tap certain reservoirs which have hitherto been tapped only by the introspective method."[9] The conditioned reflex was to be used as a substitute for introspection. It would seem, therefore, to be a valuable piece of research to determine a threshold by the two methods. No matter how the

results would turn out they would be valuable. If the thresholds were identical one might raise the question, why make use of the cumbersome procedure of the conditioned reflex when the same thing could be more simply determined by introspection? If they were not identical, one might well ask what guarantee have you that they measure one and the same threshold of discrimination?

The present study commenced with an attempt to compare the threshold obtained by the method of introspection with that found by the conditioned reflex procedure. As will be seen, this met with special difficulties; so that the final comparison was not that between these two thresholds, but that between the latent period of the conditioned reflex and that of an ordinary discrimination reaction.

THE EXPERIMENTAL PROBLEM

The purpose of the work is the investigation of the problem we have just mentioned: the study and analysis of the conditioned reflex. Is the conditioned reflex a purely mechanical action, reflex in nature, or is it a reaction involving mental factors? Is it mediated by what we term consciousness? Can we obtain any experimental evidence which will help us to answer this question? It seems likely that some light would be thrown on the problem if we could measure the difference between a threshold determined by the ordinary method with appeal to consciousness and the threshold developed as a conditioned reflex. It is, by the nature of the problem, difficult to call in the aid of introspection. Nevertheless, some information might be obtained on the nature of the "conditioned reflex" by noting the chance remarks of the subjects during the course of the experiments. Besides this, one may ask them to give their introspections from memory after the "reflex" is established. We may also determine the reaction-time of this "reflex" and compare it with the latent period of other reflexes as well as the reaction times measured by the usual reaction time experiments.

We determined, therefore, to attempt:

1. To measure the threshold of the conditioned reflex as com-

[9] J. B. Watson, Psychol. Rev., March, 1916, p. 101.

pared with the threshold determined by the usual methods, which involve an appeal to conscious discrimination. As will be seen later, the determination of this threshold was given up for special reasons.

2. To measure the latent time of the conditioned reflex.

If it were possible to get introspections during or after the development of the conditioned reflex, these would certainly throw some light on the process of its development. We attempted at first to treat the subjects purely as animals, until the conditioned reflex was fairly well developed. We then asked them what they had experienced in the course of the experiments and made no further use of them as subjects. We noticed, however, that their spontaneous remarks threw no little light on what was happening during the development of the "conditioned reflex." We therefore determined to try a second set of experiments (Part II, Section I), during which we would ask the subjects from time to time what they experienced.

Naturally, the first set of experiments was absolutely necessary in order that we might reproduce the original conditions for the conditioned reflex. For we must attempt to keep the subject wholly in the dark as to the nature of the experiments and give him a chance to develop a real reflex action of withdrawal rather than a voluntary reaction to the fear of pain.

Twenty-three men in all acted as subjects in these experiments—thirteen in the first and ten in the second section. The subjects were all students at this University, graduate and undergraduate, with the exception of Dr. Ulrich, who volunteered as subject in one or two sittings. Only he among our subjects knew the nature of the experiment. Eight others had a little training in Psychology.

The subjects were: Messrs. Walsh (W.), Antoninus (B. A.), Mooney (M.), B. Sylvan (B. S.), Brady (B.), Fr. O'Connor (Fr. O'C.), B. V. Hamilton (B. V. H.), B. V. Engel (B. V. E.), Solnitzky (S.), Nugent (N.), McDonald (McD.), Dr. Ulrich (Dr. U), Coyne (Cy.), Toole (T.), Charles (C), Hetfield (H.), Thibeau (Th.), V. Shields (V. S.), Furfey (F.), Mahoney (M.), Maus (Ma.), and Cox (Cx.).

SECTION I

TACTUAL DISCRIMINATION

The Apparatus

The apparatus in this experiment was much the same as that described by Watson in his article entitled "The Conditioned Reflex and Its Use in Psychology."[1]

It consisted (a) of a board (see Fig. 1) for the subject's hand, with a tambour for recording his reaction, and electrodes connected with the secondary of an induction coil; (b) of a drum with three electro-magnets to record what Watson terms the positive and negative stimuli and also the shock or punishment; (c) of an induction coil for giving the shock; (d) of a specially constructed touch stimulus apparatus, which made an electric contact when placed lightly against any object—in these experiments the volar surface of the forearm. By means of a switch the current could be thrown to either of the two recording magnets. When Magnet II was in circuit the subject was touched at a marked spot—the central spot. When Magnet III was in circuit the subject was touched at a spot about six centimeters above the central spot. Magnet II therefore recorded the negative stimulus and Magnet III the positive.

The detailed arrangement was as follows:

The board was supplied with two electrodes—one, a large plate (E; see Fig. I) set in the middle on the surface, and the other, a small metal ring (E^1), which lay upon the surface of a tambour (A) fastened to one side of the board. These two electrodes were connected through binding posts to the secondary coil of an inductorium (I), which in turn was connected by a switch (S^1) to the storage batteries through a signal marker. The tambour (A) was connected to another tambour (A^1), which was in contact with a revolving smoked drum. An electric contact-touch key (K) was simply devised. It consisted of a metallic spring band about 3 cm. wide, which was bent somewhat into

[1] Psychol. Rev. Vol. XXIII, No. 22, p. 89-116.

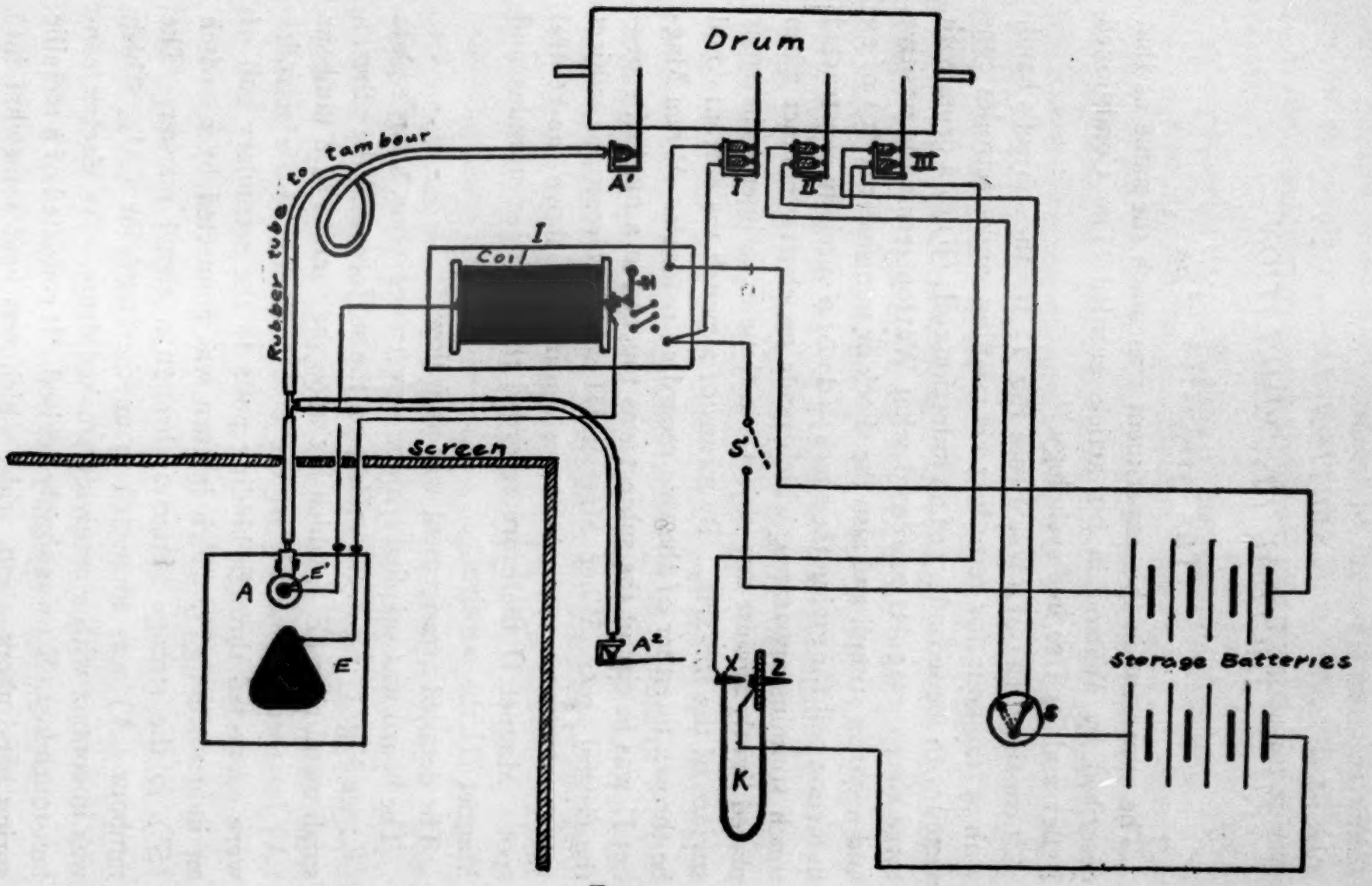

Drum
Rubber tube to tambour
A'
I
II
III
I
Coil
S'
Screen
A
E'
E
A²
X
Z
K
S
Storage Batteries

FIG. 1.

the shape of an elongated horseshoe with its two ends close together, so that the slightest pressure exerted at one end would bring it in contact with the other end. ~~The end~~ (X) was insulated, and a small binding post was inserted into it so that it extended to within 2 mm. from the end (Z). The end was supplied with another binding post and a metallic touch-point. The two ends of the key were connected to the batteries through a double switch (S) leading to two magnetic signal markers, which registered on the drum. A screen shut off all of the apparatus from the subject except the board and the two electrodes. The electric current was supplied by storage batteries, connected in such a way that a strength of six, ten, or twelve volts could be sent through the inductorium. A voltmeter was in circuit. ~~Six~~ volts were used for the first group, ten volts for the second, and the whole strength for the last group of subjects. The apparatus for recording the finger reaction was different from that used by Watson. Instead of fastening the tambour on top of the finger which rested on the electrode, we placed the small electrode on top of the receiving tambour and had the subject rest his finger on it. Thus the mere placing of the finger upon the electrode was felt by the receiving tambour on the drum. Another signal tambour (See Fig. I, A2) was placed in the same circuit with the other two and was supplied with a long pointer. This was placed in front of the experimenter, so that he could easily observe when the subject reacted.

Procedure

The subjects were given no instructions at all. They were merely placed in position like an animal. They were, however, asked to mention the experiment to no one. Seated at the table near the board, the subject's left hand was placed with the palm resting upon the plate electrode and the tip of the middle finger resting upon the small ring which lay upon the tambour. The slightest movement of the finger, therefore, registered upon the kymograph. The right arm was bared to the elbow and was placed comfortably upon the other side of the screen. The ex-

perimenter then picked out a certain spot on the volar surface of the subject's forearm near the wrist (called the "central spot"), and another spot, about 6 cm. further up on the arm towards the elbow. With the kymograph running on low gear and with all electro-magnetic markers and tambour set, the experimenter then lightly touched the subject's skin at the "central spot," with the contact-touch key six, four, five, or maybe nine times at equal intervals (the number of touches was made as varied as possible). Each of these taps registered on the kymograph, and are what Watson would call "negative stimuli." Then the double switch was thrown, and the subject was touched at the point further up on the arm (the "positive stimuli") and was simultaneously shocked. This process (which we will call a *trial* for convenience) was repeated five or six times, and then the subject was touched at the point away from the central spot without the shock. If he did not react withdrawing the finger (and at first he never did) the shock was then given as punishment and the whole process would be repeated.

The experimenter handled the contact-touch instrument with one hand and worked the switches with the other. After a little practice this was easily done.

A smoked drum record was obtained which registered the touches at the central spot (called the negative stimulus); the touch at the spot further up on the arm (called the positive stimulus); the introduction of the faradic stimulus (shock or punishment); and the movement of the finger (as given by the tambour). (See Fig. II.)

The experiment was repeated again and again with a subject until he reacted, when the positive stimulus was given, i. e., had developed the "conditioned reflex." We did not push the experiments of this section until the response to the positive stimulus was absolutely constant, but were satisfied when the subject nearly always reacted to the positive stimulus without being shocked.

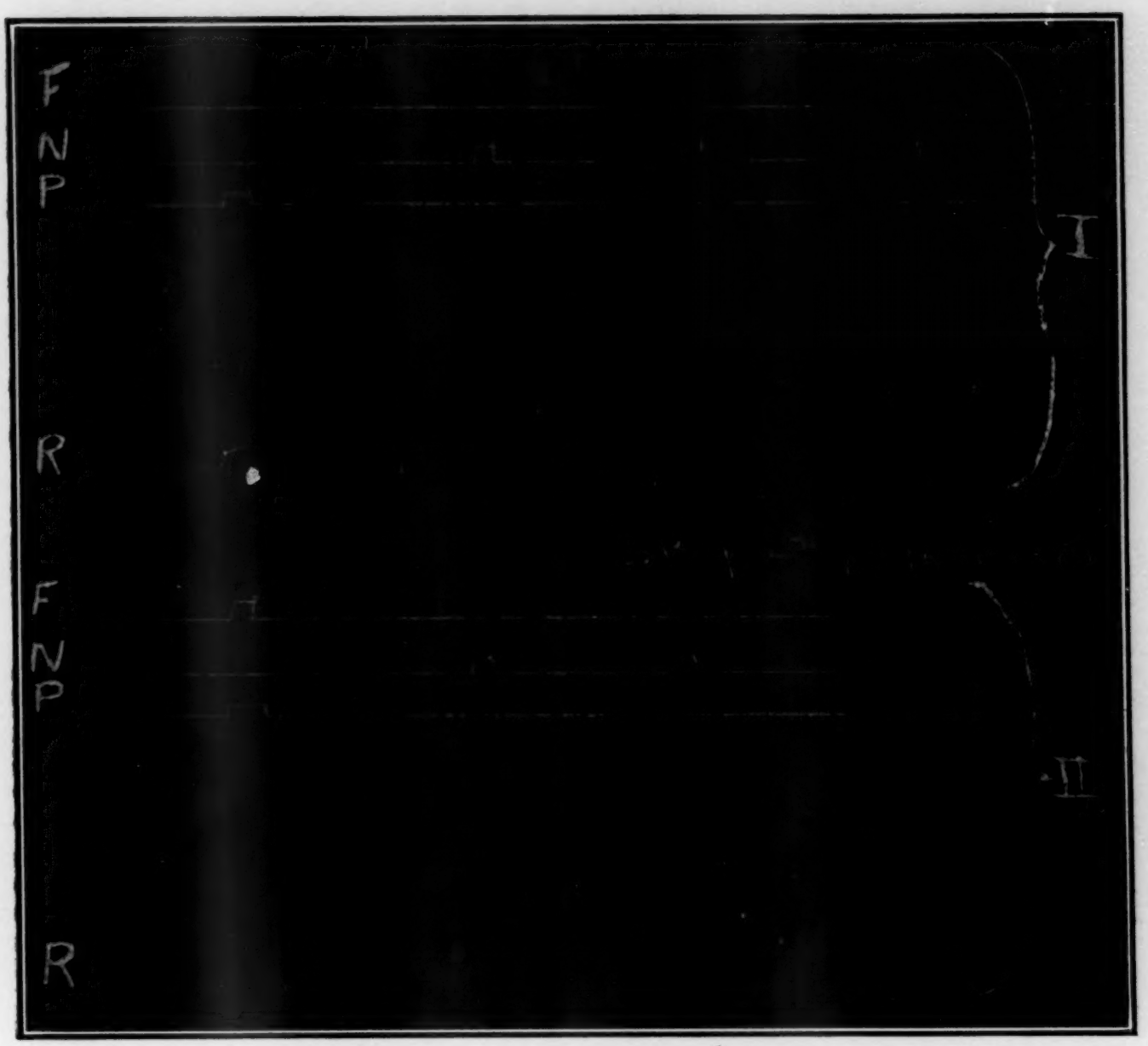


FIG. 2. Kymograph Record showing: I. A conditioned reflex (reaction to touch alone—positive stimulus—without shock). II. A complete "trial." F, Faradic stimulus (shock); N, negative stimulus; P, positive stimulus; R, reaction of finger as recorded by tambour. Subject (S.)

Experimental Data (Part I)

The results of each individual subject in this experiment are tabulated below. They are given as far as possible in the order in which they served as subjects. Each subject averaged from 17 to 22 trials at every sitting. Each trial, as was stated before, consisted of a complete process, i. e., an indefinite number of touches at the "central spot" of the forearm, followed by a touch further up on the subject's arm nearer the elbow, accompanied by a shock.

The trials upon which the subjects responded to the positive stimulus without the shock are numbered according to the number of trials the subject had had previous to his reaction. Thus, Subject (M) had sixty-five trials (was shocked sixty-five times with the positive stimulus) before he responded (on the sixty-sixth trial) without the shock, i. e., a "conditioned reflex." He was then shocked (punished) eight times before he again reacted without the shock (on the seventy-fifth trial), etc. Each subject's introspective account (in this part) follows his respective list of "conditioned reflexes."

The data are as follows:

Subject (W). Graduate student in Psychology. Seven sittings; 140 trials. No reaction without the shock. Subject caught on to what the experimenter wanted, saying, "You are trying to get me to react when you touch me upon the arm without the shock." Subject was excused.

Subject (B.A.). Graduate student in Psychology. Also became aware of what the experimenter wanted, after two sittings (40 trials). He overheard something indirectly concerning the nature of the experiment. Subject excused.

Subject (M.). Undergraduate student—138 trials. Reacted to touch alone (without the shock), i. e., responded to the positive stimulus on the following trials: 66th, 75th, 81st, 87th, 98th, 103rd, 104th, 107th, 109th, 111th, 113th, 116th, 120th, 123rd, 124th, 125th, 130th, 132nd, and 137th. (Introspection was then asked for): "Felt myself all the time wanting to pull my finger away. After you tapped me a certain number of times I expected

a shock, but I didn't know when it was coming, because of the irregularity of the taps."

Subject (B.S.). Graduate student—218 trials. Reacted to touch alone (without the shock) on the following trials: 79th, 84th, 119th, 134th, 159th,[2] 162nd, 167th, 178th, 187th, 191st, 194th, 197th, 199th, 200th, 201st, 202nd, 204th, 205th, 206th, 207th, 208th, 209th, 210th, 211th, 212th, 213th, 214th, 215th, 218th. (Introspection was then asked for): "I expected a shock when you touched me away from the central spot."

Subject (B). Undergraduate student—210 trials. Reacted to touch alone (without the shock) on the following trials: 30th, 43rd, 55th, 66th, 74th, 79th, 86th, 90th, 97th, 103rd, 106th, 110th, 111th, 112th, 113th, 117th, 118th, 119th, 120th, 121st, 122nd, 124th, 125th, 129th,[3] 131st, 133rd, 136th, 137th, 138th, 140th, 142nd, 144th, 148th, 150th, 152nd, 154th, 155th, 156th, 158th 163rd, 166th, 169th, 170th, 171st, 173rd, 177th, 181st, 183rd, 185th, 187th 188th, 190th, 193rd, 196th, 197th, 198th, 199th, 200th, 202nd, 204th, 205th, 206th, 207th, 210th. (Introspection was then asked for): "I knew when the shock was coming, so I reacted every time you touched me up nearer the elbow. If I did not react you would shock me. I caught on to this about three or four days before the last trial."

Subject (Fr. O'C.). Graduate student—29 trials. Reacted on 29th trial and laughed. Told experimenter he "did not get the shock that time." This subject did not have the time to continue the experiment.

PART II

In the previous experiments the subjects were asked for one introspective account only, and that at the end of the experiments, after the "reflex" was more or less developed. In the following

[2] Guessing when he thinks shock is coming. Trying to outguess the experimenter, and sometimes raises his finger to avoid the shock. (This information was given to the experimenter by Subject B.A., who was no longer used and who asked him about the experiment. Subject B.A. gave him no information.)

[3] About at this period, the subject (as he tells us in his introspection) began to "catch on."

experiments they were asked for introspective accounts at different times in the course of the experiment—during the period when the "reflex" was being developed. These introspections appear in the data below.

The method and procedure was otherwise the same, with the exception that ten volts were sent through the inductorium instead of six.

Experimental Data (Part II)

Subject (B.V.H.). Graduate student in Psychology. Reactions to touch alone (without shock) on the following trials: 14th, 20th, 23rd, 29th, 31st, 33rd, 39th, 46th, 48th, 51st, 53rd, 62nd, 65th, 70th, 73rd. (On the 23rd trial introspective account had been asked for: "The very first thing was the inclination to pull my hand away when I thought the shock was coming. Thought of pulling my finger away was continuously present." On the 73rd trial another introspective account was asked for: "Always expected the shock when you touched me high up on the arm. I jerked my finger sometimes when I expected the shock, but I was fooled, as I did not get it.") (Experiment continued): 77th, 82nd (here the experimenter tried for a reaction and did not get it. The subject was then shocked, to which he remarked, "I thought I had skipped the shock, but I got it late."), 85th, 86th, 95th, 97th, 99th, 103rd, 104th. (Introspection asked for): "Twice in succession to-day you touched me up on the arm and I did not raise my finger enough to leave the brass electrode, but I might have jerked it a little."

Subject (B.V.E.). Graduate student in Psychology. Reactions to touch alone (without shock) on the following trials—32nd, 37th, 51st, 52nd. (Introspection I asked for): "Always a temptation to pull away my finger—greatest when I think the shock is coming, but I don't know when it is coming. Continual dread of shock; try to prevent the jerks in my arm, but impossible. Anticipation of the shock is worse than the shock itself." —60th, 61st, 62nd. (Introspection II asked for): "Tried to avoid shock by pulling back finger. Pulled finger away when you touched me up on the arm" (pointed where)—66th, 67th,

69th, 70th, 75th, 77th. (Introspection III asked for): "Shocks seemed stronger to-day. I pulled my finger away whenever I thought the shock was coming."—82nd, 89th, 94th, 95th, 97th, 98th, 101st, 102nd, 103rd. (Introspection IV asked for): "I wanted to keep finger on when I felt shock was coming, but pulled away involuntarily."—109th, 110th, 115th, 116th. "I avoid the shock by pulling my finger away sometimes."

Subject (S.). Graduate student in Psychology. Reacted to touch alone (without shock) on the following trials: 11th—(Introspection I): "At first my mind was in a state of expectancy, not knowing what will happen. Soon I felt the light touches of the instrument in the experimenter's hand on my skin. When a spot further up on the skin was touched, the other hand, which was resting over the metallic plate, was withdrawn.[4] . . . After that the first taps on the skin next to the wrist were followed by a tap further up, accompanied by a shock. Then, every time this shock was expected, the pain was more acute at the base of the nail of the middle finger, which was resting on the metal ring. At the end of the experiment a feeling of relief was experienced."—16th, 17th, 20th, 22nd, 26th. (Introspection II): "This time the memory of the painful impressions from the previous experiment asserted itself to a comparatively great extent. Imagination played its part, too, so that sometimes the arm was withdrawn before the 'climax' in the electric charge was reached." 35th. (Introspection III): "There was no feeling of expectant pain to-day. My mind was very much occupied, as I had some hard work to do after the experiment. The result was that the withdrawal of the hand was very sudden, whereas, when I directed my attention to the pain sensation, this was not the case."—38th, 39th, 40th, 41st, 45th. (Introspection IV): "Tried to count the taps below before you touched me up higher. After the first trial I counted them. First it was six, then seven, then others, and I lost count. Expected shock when you touched me up here (showed experimenter). Twice to-day I was expecting shock and did not get it, and I did not lift my finger. How-

[4] Referring to the trials previous to the 11th, when he was shocked.

ever, I had the finger all ready for it."—53rd, 60th, 63rd, 68th, 69th, 75th, 76th, 78th. (Introspection V): "More intense shock to-day. Sometimes the finger was withdrawn before I got the shock."

Subject (N.). Undergraduate student.[5] Reacted to touch alone (without shock) on the following trials only—34th and 82nd. The introspective account after the sitting in which the first "conditioned reflex" appeared is as follows: "There is always a shock up here (pointed where), except once to-day I was expecting it and it didn't come. However, I was set for it and I perhaps jerked a little bit." The introspection after the 83rd trial: "I get all set to withdraw the hand and sometimes the shock doesn't come. I get set for it. It is just like when you are expecting a blow and you get all set for it, and you even jump."

Subject (McD.). Undergraduate student. Reacted to touch alone (without shock) on the following trials: 20th, 24th, 27th. (Introspection I): "I was trying to figure out the system of taps before the shock came. It was too varied. Always a few taps before you tap me up on the arm, then the shock comes." (The subject thought he was getting a shock in the right arm, too, where he was stimulated.)—36th, 37th, 42nd. (Introspection II): "Every time the shock had to come when you touched me nearer the elbow. A couple of times to-day I expected it and it didn't come. I thought I was going to get it and I reacted some. A peculiar sensation." 52nd, 56th. (Introspection III): "I did not release my hand from the ring to-day. Twice I got no shock, but I did not jump, as in previous days, when it didn't come."

Subject (Cy.). Undergraduate student. After the first shock he could not keep his hand on the electrode. He stated that he received a severe electric shock when a young boy, and ever since then he has not been able to stand any kind of electricity.

Subject (Dr. U.). This subject knew the nature of the experiment and volunteered a sitting. He reacted without the shock

[5] This subject was used in the next series of experiments.

on the seventh trial. He naturally expected a shock from the first, but after the first shock he claimed a "greater anticipation." "My finger trembled, and I could not keep it steadily on the plate."

DISCUSSION OF RESULTS

Considering these introspections, we find the following which might indicate that some kind of a reflex was being developed:

Subject (M.): "Felt myself all the time wanting to pull my finger away."[6]

This was a rather general experience and not peculiar to this subject. Similarly, subject (B. V. E.): "I wanted to keep my finger on when I felt that the shock was coming, but I pulled away involuntarily."[7]

Subject (B.V.E.) not only feels that he wants to pull away, but actually does so involuntarily. Subject (S.) also reports that "sometimes the arm *was* withdrawn before the 'climax.' "[8]

It would therefore seem that there was a good deal of reflex activity going on during the development of the "conditioned reflex." This reflex activity, however, has a distinct relation to the conscious fear of being shocked—not to the stimulus on the upper part of the arm itself. We have no evidence from the introspections to show that the fear is transferred from the idea of the shock to that of a touch on the upper part of the forearm, or that the mere touch on a special point of the skin elicits, without any further consciousness, a tendency to react. The possibility, therefore, of determing the threshold by this method, for the purpose of comparing it with the conscious threshold of discrimination of touch spots seemed to us rather hopeless. If this method were continued we no doubt could have obtained a threshold, but it would be one obtained through a conscious discrimination. We found that we never got it even approaching

[6] Supra p. 32.
[7] Supra p. 35
[8] Supra p. 35.

perfect development without the reaction being evidently dependent on consciousness. Let us suppose that we had developed the threshold by this method; we might then have compared it with a similar threshold determined by one of the ordinary methods which depend on conscious discrimination. Comparing the two thresholds, one of two things would have to result: they would be the same within the limits of probable error, or they would be manifestly different.

Let us suppose that the threshold were approximately identical. We might then assume that we were measuring the same reflex arc or series of arcs by two different methods. The improved method, involving no appeal to consciousness, could only be regarded as a confirmation of the accuracy of introspection.

Suppose that we would get decidedly different thresholds. Then we could never be sure that we were dealing with identical sets of phenomena. The introspective threshold would be an independent value interesting in itself and not to be thrown away as a mere inaccuracy.

We then see that the "conditioned reflex," if any such thing really exists, cannot be used (as Watson thought) to supplant the introspective method. If it is a real reflex, and not a reaction dependent on an act of consciousness, it has a value separate and distinct from conscious responses, and is to be studied for its own sake and not to supplant all introspective appeal. As a matter of fact, we never obtained a well-developed "conditioned reflex," except in subjects who eventually got an insight into the fact that they would be punished unless they reacted to a certain stimulus.

This being the case, it seemed to us hopeless to get a true reflex response to the positive stimulus, for it was very clear that the subjects were not reacting in a reflex manner, but that their response was clearly determined by a conscious discrimination.

CONCLUSIONS

(Section I)

1. It appears that the factor of expectancy[9] was at first uppermost in the minds of all the subjects, as revealed in their introspective accounts. After the first few trials (accompanied by the shock) they all report that, following a few taps on the arm at the central spot (negative stimuli), a shock was looked for when they were touched by the positive stimulus (at a spot further up on the arm).

2. Characteristic remarks of the subject, such as, "I expected the shock, but I was fooled, as I did not get it," and "I did not get the shock that time" (laughing), "I thought I was going to get it that time and I reacted some," etc., before the reaction was even fairly well established, reveal the fact that the phenomena which are wont to be called conscious certainly were involved.

3. In all cases where the reaction was more or less completely established the subjects were fully aware of what they were doing. Subject (B.) explicitly stated that "I reacted every time you touched me nearer the elbow. If I did not react you would shock me." Such a response is certainly more complex than any reflex action. It appears to involve a discrimination between the negative and positive stimuli.

SECTION II

The Reaction Time of the Conditioned Reflex

From the previous experiments it seems likely that the so-called conditioned reflex depends upon a conscious element for its development. It was decided to seek further evidence on the nature of this reaction by an attempt to measure its latent period. Having obtained this, it could be compared with the latent period

[9] This factor of expectancy, if we are permitted to call it such, was very noticeable to the experimenter who observed that the subjects would at times jerk away from the electrodes before the positive stimulus was given—apparently thinking that the next tap would be that of the positive stimulus which was followed by the shock.

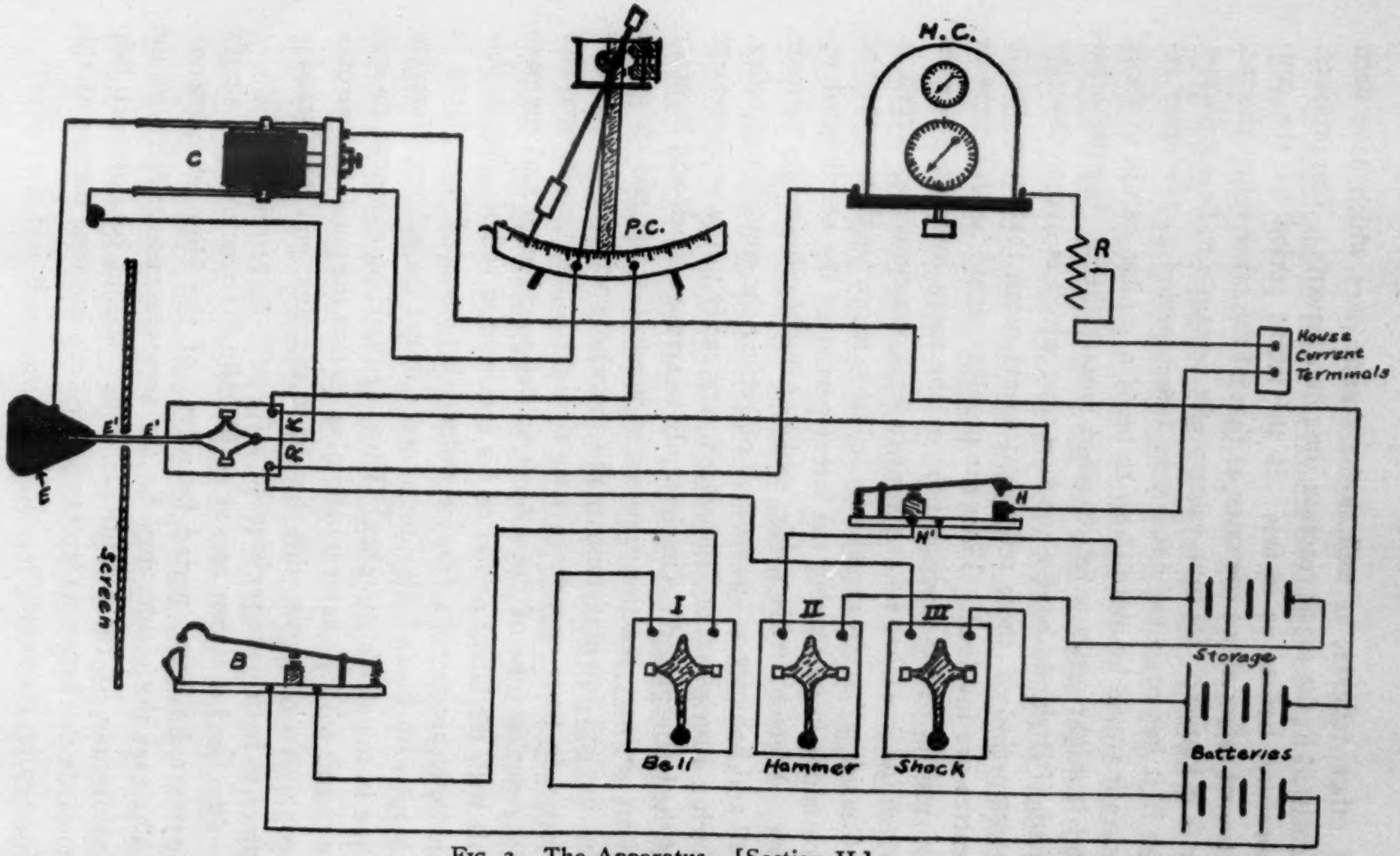


FIG. 3. The Apparatus. [Section II.]

of other reflexes, as well as the similar ones which have been measured in the usual reaction time experiments. The problem, therefore, before us is this: Is the latent period of the conditioned reflex about the same as that of the other reflex actions, or is it longer? Its time value ought certainly to be significant, for if it has practically the same latent period as the other reflexes it would be more likely to be of a similar nature to them, and it might perhaps be classified among them. On the other hand, if it should have a reaction time which is longer than the latent period of these reflexes it would mean that other neural centres are involved. Then the problem would be to determine its relation to the reaction time of the more complex processes which involve what we are wont to term conscious phenomena.

Considerations of expediency led us to adopt another method of procedure in measuring the latent period of the conditioned reflex. Watson, in his article, spoke of the discrimination between bell and hammer as one method of getting the conditioned reflex. Such a discrimination lends itself very easily to the measurement of the latent period. One has only to arrange a bell and hammer in an ordinary reaction time set of apparatus and add on an induction coil for punishment, and the whole arrangement is complete. In these experiments we thought it well to measure also the reaction time of the subject to the punishment and compare this with the latent period of his conditioned reflex. To do this another chronoscope (the pendulum chronoscope) was placed in circuit with the inductorium in order to get the subject's reaction time in the shock stimulus. Thus, as the Hipp chronoscope was in circuit with the hammer stimulus, so that the pendulum chronoscope was in circuit with the shock stimulus, and the reaction times to both were registered.

One need not then record graphically the reaction, but simply measure its latent period by means of the Hipp chronoscope. Whatever the results may be, the accurate measurement of the latent time of the conditioned reflex should be a distinct help towards the better understanding of the intimate nature of this interesting phenomenon.

The Apparatus

The apparatus in this experiment consisted of the following parts:

a. A metallic plate (E) (see figure III, used as an electrode, upon which the subject placed the palm of his right hand.

b. An ordinary reaction key (R. K.) fitted with a small metallic rod about twenty-five centimetres long, at the extreme end of which the subject rested the middle finger of his right hand. This rod was used as the second electrode (E′), and the key was so adjusted that the slightest reaction of the subject's finger broke an electric contact.

c. A Hipp chronoscope (H.C.), connected in circuit with the subject's reaction key and a magnetic sounding hammer (H). This circuit was connected to the house current through a rheostat (R).

d. A magnet sounding hammer, the magnets of which (H^1) were connected to the storage batteries through a switch (II), which was operated by the experimenter. By means of this switch, then, the experimenter sounded the hammer (this was called the "positive" stimulus)—which, in turn, closed the circuit through the Hipp chronoscope and the subject's reaction key, starting the chronoscope. The reaction of the subject (when he did react to this stimulus) broke the circuit, stopping the Hipp chronoscope.

e. A magnetic signal bell (B), which was connected to the batteries through another switch (I), operated by the experimenter, was used as the "negative" stimulus.

f. The inductorium (C) was used for giving the shock or punishment. The secondary of the inductorium was connected to the two electrodes. The primary of the inductorium was connected through the pendulum chronoscope, the subject's key, a third switch (III), operated by the experimenter, and the storage batteries, in such a way that as soon as the shock was given the pendulum chronoscope started to swing, and as soon as the subject reacted it stopped the pendulum chronoscope.

Three switches, therefore, were operated by the experimenter

(see figure III). The first switch (I) simply rang the bell (the negative stimulus); the second switch (II) sounded the hammer (the positive stimulus) and started the Hipp chronoscope, the subject's reaction—if he did react—stopping it. The third switch (III) administered the shock and started the pendulum chronoscope simultaneously. The Hipp chronoscope measured the reaction time to the positive stimulus, and the pendulum chronoscope measured the reaction time to the shock. A screen shut off all the apparatus from the subject. The full strength of the storage batteries (twelve volts) was sent through the inductorium. A volt-meter was in circuit.

Procedure

The subject sat at a table, resting his hand comfortably upon one electrode and his finger of the same hand on the other. The chronoscopes having been set, the experimenter rang the bell (switch I, the negative stimulus) two, three, five, or maybe eight times. (The number was made as varied as possible). This was followed by the sounding of the hammer (switch II, the positive stimulus). The experimenter kept this switch closed and watched the Hipp chronoscope, which had started at the tap of the hammer. If the subject reacted to the hammer (which he never did at first) the Hipp chronoscope stopped moving and the reading was taken from it. If he did not react to the hammer (as the experimenter could easily detect from his observation of the Hipp chronoscope, which in this case continued to move) the shock or punishment (Switch III) was immediately given. This switch simultaneously started the pendulum chronoscope, and the subject's reaction to the shock stopped the pendulum as well as the Hipp chronoscope. The reaction time to the shock was then taken from the pendulum chronoscope. This complete process we will call a "trial," for convenience.

The experimenter then took the new reading of the Hipp chronoscope and readjusted the pendulum, whereupon a new trial was begun. The trials were repeated again and again until the subject began to react to the positive stimulus without the shock,

i. e., until the "conditioned reflex" was obtained, and these readings were all taken from the Hipp chronoscope.

The casual remarks of the subjects given while the experiments were in progress were all carefully noted, and appear in the data at the exact place in the experiment where they were given by the respective subjects. These were, however, considered of secondary importance in this section of the work; nevertheless, they were conspicuous in revealing what was going on in the minds of the subjects, as will be seen below.

Control readings were taken from the Hipp chronoscope before and after the sittings. We found a small, variable error of from two to three sigma, which proves to be of little importance. The pendulum chronoscope was also tested several times for control readings, and, although it measured only in hundredths-seconds, it proved to be surprisingly constant.

The subjects were entirely uninformed concerning the nature of the experiment, and were treated (as in the previous experiments) as much as possible like animals. They were asked to mention the experiment to no one.

EXPERIMENTAL DATA

Experiment With Single Weak Shock (Preliminary)

A weak shock was at first tried without success (the "make" shock of the inductorium). Five subjects were given many trials, but no "conditioned reflexes" appeared. The results follow:

Subject (F.). A graduate student in psychology. Eighty trials were given and he did not react at all to the hammer alone, i. e., he was shocked eighty times, and even then, when offered the hammer without the shock, he did not react. This subject later informed himself of the nature of the experiment and was no longer used.

Subject (Ma.). A graduate student. Was given 45 trials, and subject (M.), an undergraduate student, was given 60 trials, but no reactions appeared without the shock.

Subject (N.). An undergraduate student, who was used in the previous experiment—was given 118 trials, and no reactions were obtained to the hammer alone.

Subject (T.) An undergraduate student, was given 166 trials with like results. (Subjects N. and T. continued as subjects in the experiments to follow.)

Experiment With Faradic Shock or Punishment

The Faradic shock was then used. However, this involved a serious difficulty in getting subjects to continue the experiment after the first day. One of them—subject C., the colored janitor—had to be bribed, and even then he would not continue the experiment under any circumstances. The results follow:

Subject (N.). After eight shocks the subject responded (without the shock) on the ninth trial, saying, "I got away from it." On the next two trials (the 10th and 11th) he also responded and laughed. Reactions without the shock then came frequently on the following trials: 13th, 15th ("I am stealing on you here; I did not get it"), 16th, 17th, 18th, 19th, 21st, 22nd, and successively after that, with the exception of an occasional shock given now and then as punishment when the subject did not react quickly enough.

The time for 127 of these "conditioned reflexes" was taken, and their time-curve appears in an accompanying figure (Figure IV). The letters "S" in the curve denote that the subject was shocked at these periods in the development of this reaction. The reaction time to these shocks appears in brackets after the letter "S" in the curve.

After 127 of these "reflexes" were measured, the subject was told that he would not be shocked any more, but that he should react as quickly as possible every time he heard the hammer rap. The subject laughed and said, "I have been doing that right along." 125 of these conscious discrimination reactions to the hammer were then measured, and the reaction time curve for them appears, together with the time curve for the "conditioned

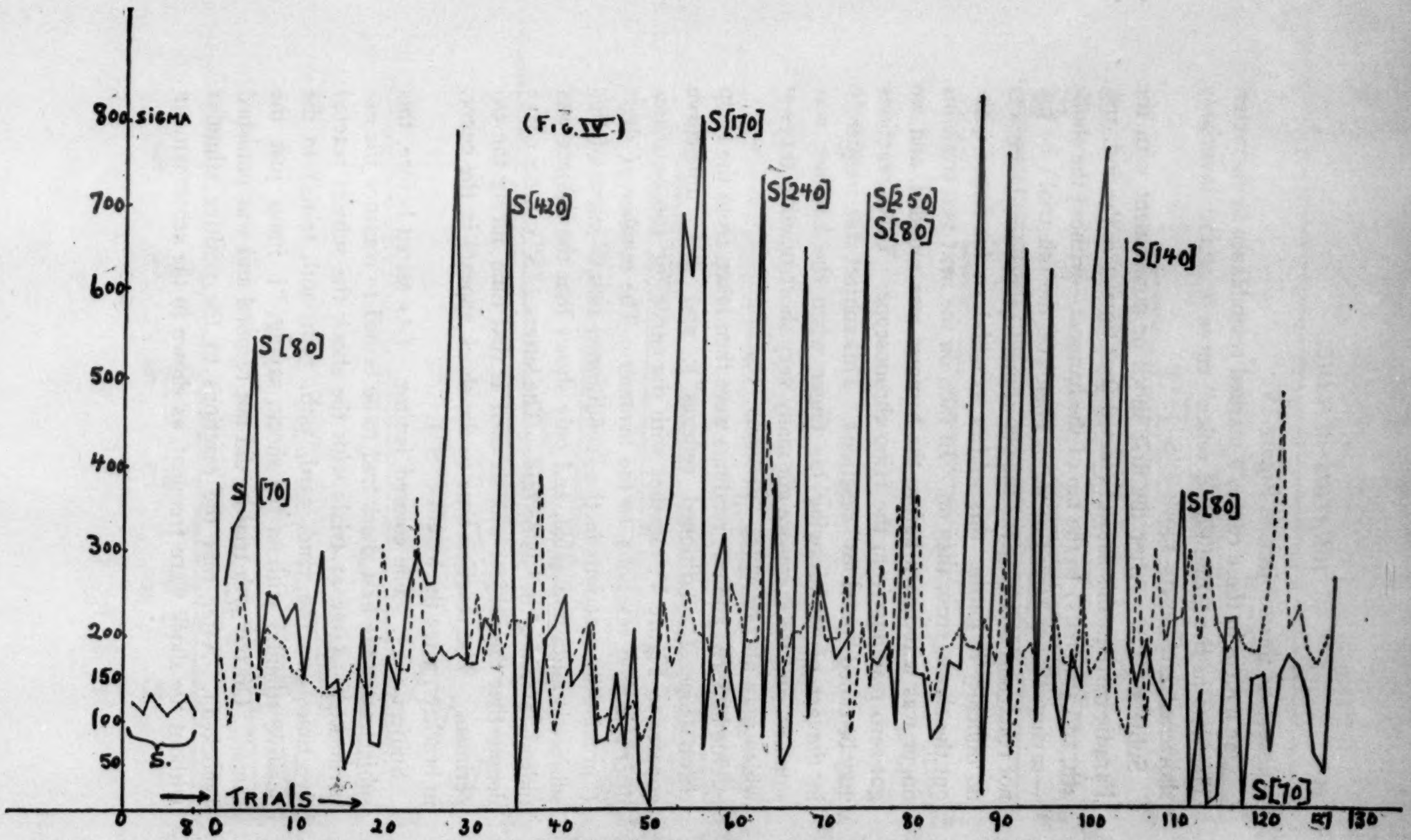


FIG. 4. Showing Conditioned Reflex curve, and conscious discrimination curve (dotted lines). Subject (N).

reflexes" of this subject, in Figure IV.

One notices in these curves a marked resemblance in character. The time in the "conditioned reflex" curve is almost invariably shortened after every shock ("S").

Subject (T.). After the first shock or punishment with the Faradic current, this subject reacted four times (on the 2nd, 3rd, 4th, and 5th trials) to the tap of the hammer—without the shock—saying, "I am afraid of it." Then (on the 6th trial) he did not react, and he was given the punishment (shock). There was no difficulty in getting this subject to withdraw his finger without the shock, from then on. In fact, on the next two trials his finger was withdrawn before the hammer was sounded, and we got zero readings from the Hipp chronoscope. These reactions may be called "previous" reactions. This subject was frequently in the act of withdrawing his finger when the hammer was sounded, and we therefore got many very short reaction times—which may also be called "previous" reactions.

One hundred and one readings were then taken from the Hipp chronoscope ("conditioned reflexes"), and their time-curve appears in Figure V, together with the curve for 100 conscious discrimination reactions, to the hammer. The number of short ("previous") reactions in the "conditioned reflex" curve of this subject is quite noticeable, and only shows that the subject was indeed "afraid of it," as he said. The letters ("S") in the curve denote that the subject was shocked at that time during the experiment. The reaction-time to the shock appears in the curve, in brackets, after the letters ("S").

Subject (C.). The colored janitor. (As stated before, this subject after the first shock had to be bribed to continue the experiment.) After 31 trials with the shock the subject reacted five times (on the 32nd, 33rd, 34th, 35th, 36th trials) to the positive stimulus without the shock, saying, "I jump just the same." On the 37th trial he did not respond and was punished (shocked). After that the reactions to the positive stimulus without the shock were frequent, as shown in the accompanying

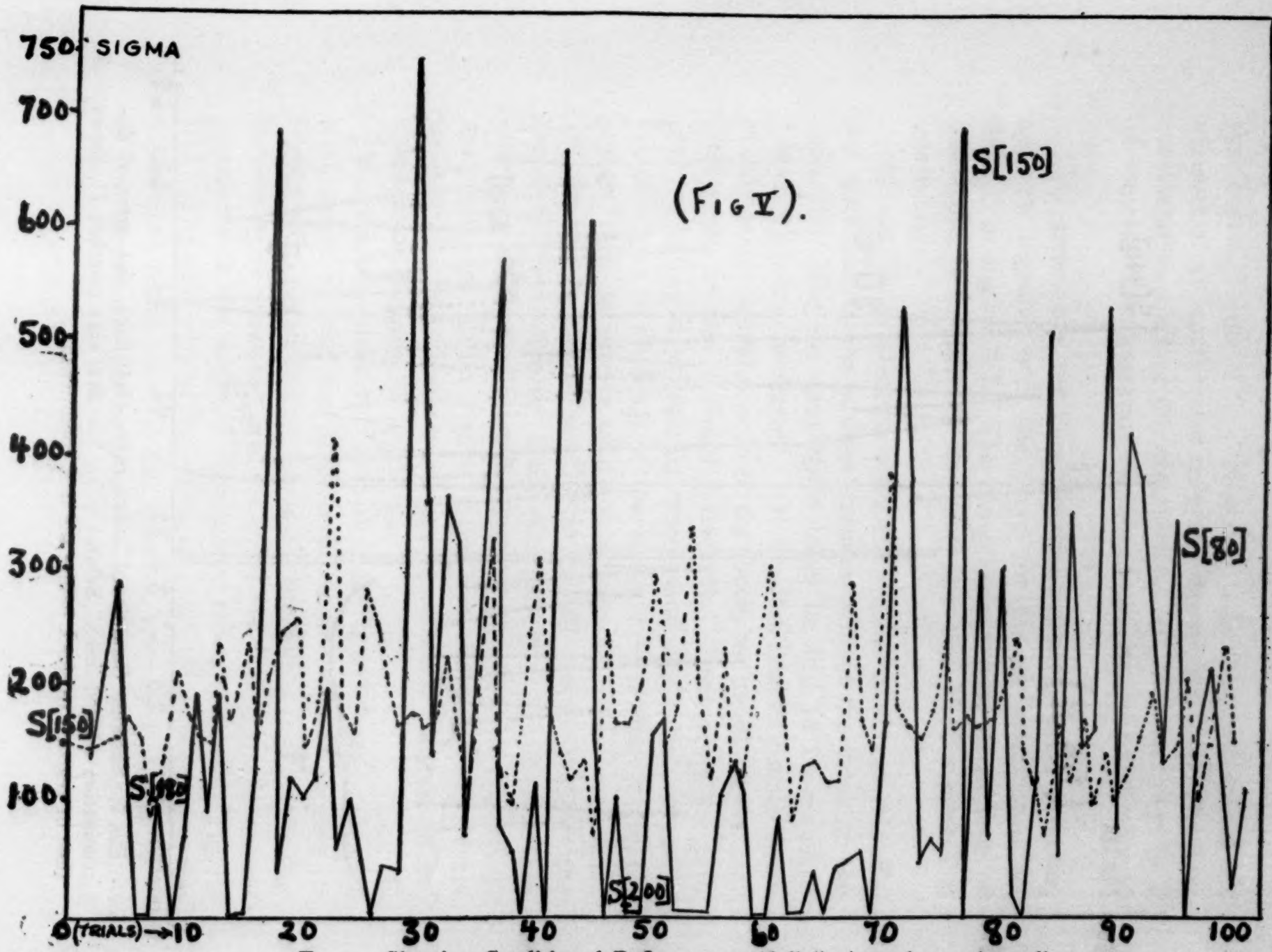


FIG. 5. Showing Conditioned Reflex curve (full line), and conscious discrimination curve (dotted line). Subject (T).

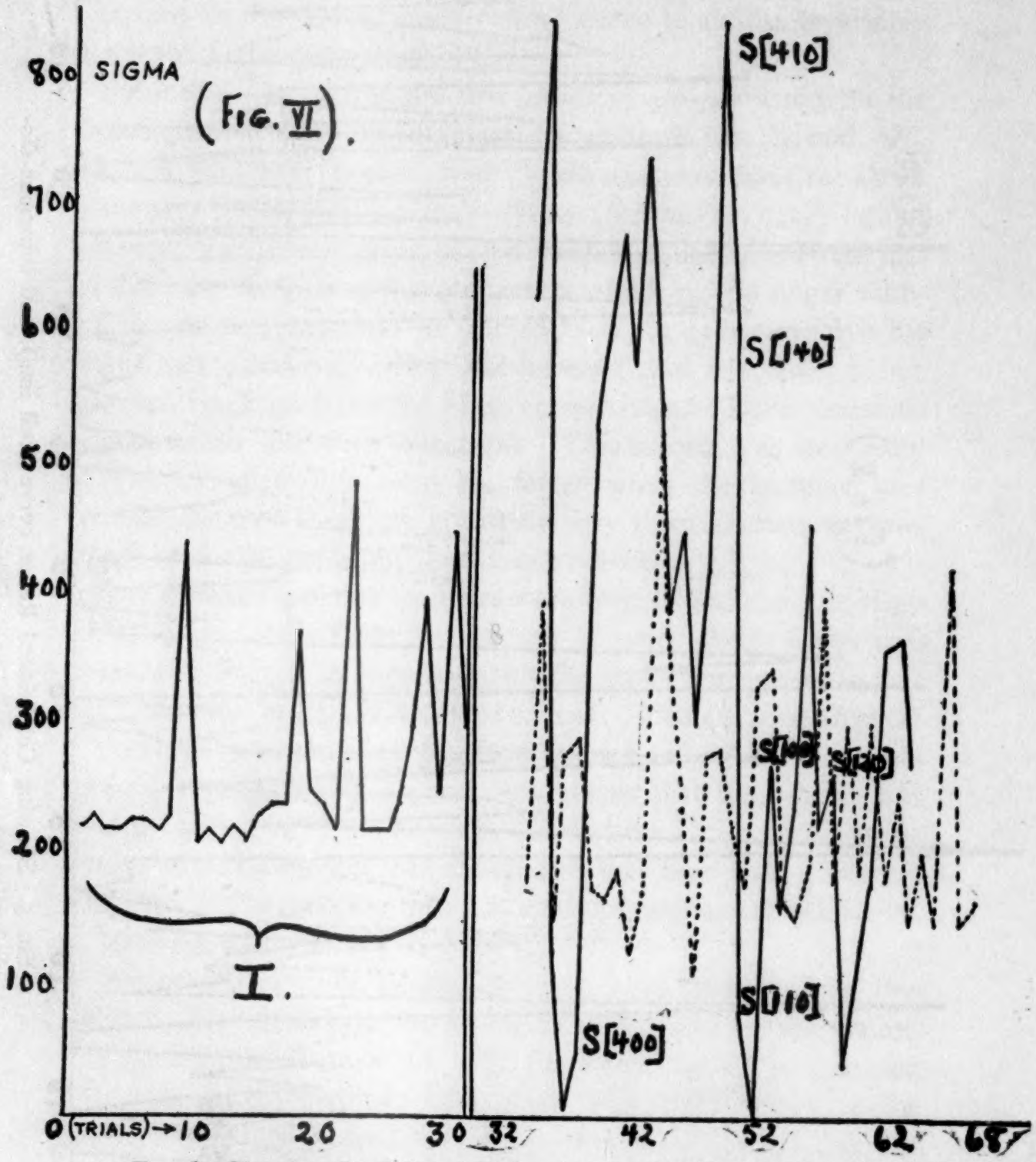


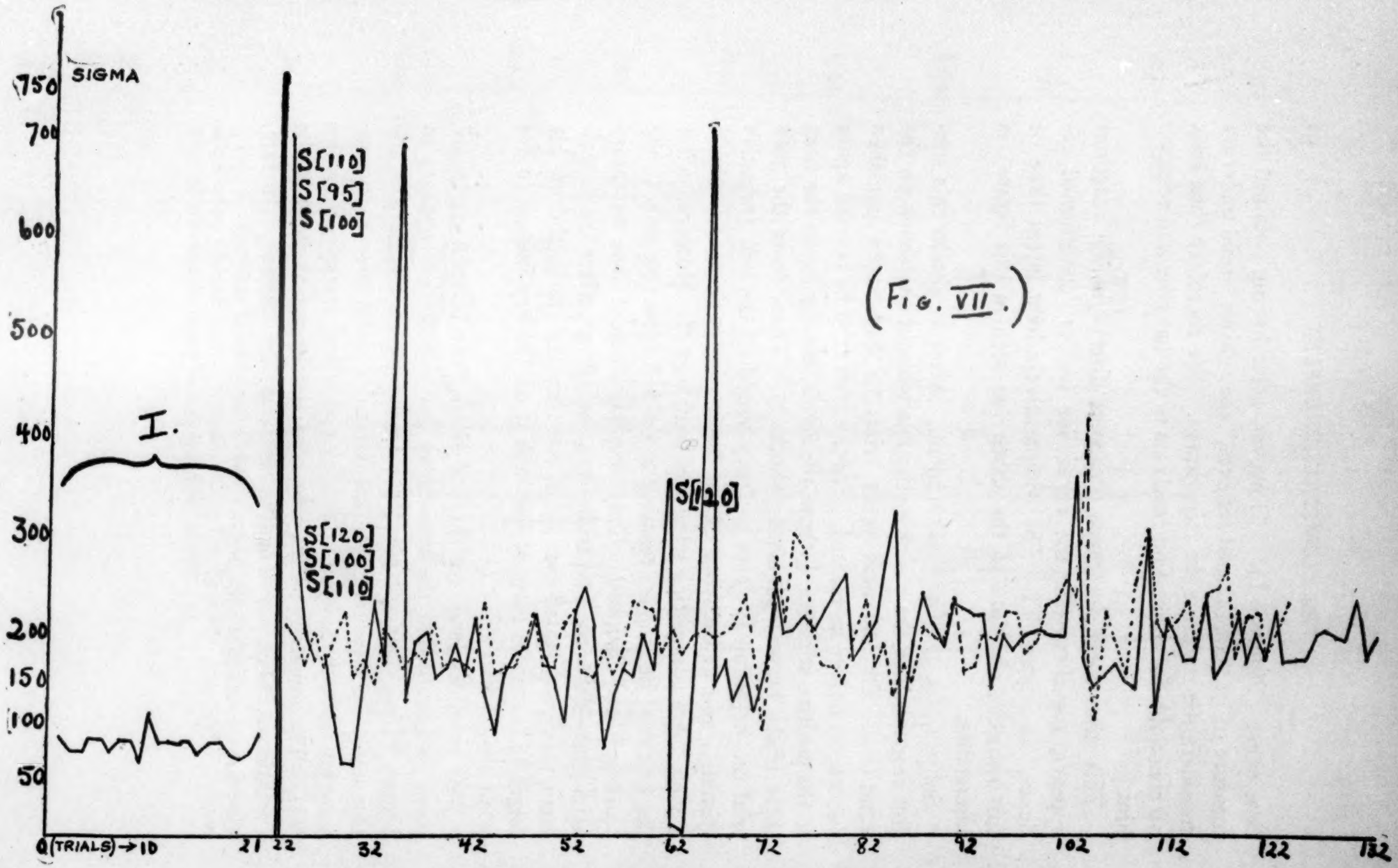
FIG. 6. Showing Conditioned Reflex curve (full line), and curve of discrimination (dotted line). Subject (C). The first part (marked I), shows time of reaction to shock before the first conditioned.

time curve (Figure VI). However, after having obtained the measure of 31 "conditioned reflexes," the subject would under no consideration continue the experiment. We therefore then took 36 conscious discrimination reactions to the hammer and released him.

This time-curve for these conscious discrimination reactions appears, together with the curve for his 31 "conditioned reflexes," in Figure VI. The comparatively long latent time of this subject's reactions to the shock (as seen in this figure) is interesting.

Subject (Cx.). Graduate student. After 21 shocks this subject responded to the positive stimulus without the shock on the 22nd trial. On the next three trials he had to be punished (shocked) before he reacted. On the 26th trial he reacted again to the positive stimulus without the shock, but again, on the next three trials, he was punished (shocked). Then, from the 30th trial on, he began to react to every sound of the bell (negative stimuli), and to each tap of the hammer (positive stimulus), saying, "Are you getting what you want now?" However, after the 51st trial he stopped reacting to the bell (reacting only to the hammer) and laughed. Only one punishment was necessary after that—after the 61st trial—and the subject, after the experiment was over, stated that he at one time did not withdraw his finger in the usual manner but kept it on the key merely to see what would happen.

The reaction-times for 111 of these "conditioned reflexes" were measured, and the time-curve for this subject appears in Figure VII. Then 102 conscious discrimination reactions to the hammer were measured, and the curve for these appears in conjunction with this subject's "conditioned reflex" curve—in Figure VII. The similarity of the conscious discrimination curve to the conditioned reflex curve in this figure is very marked. In fact, they are practically identical.



(Fig. VII.)

Fig. 7. Showing Conditioned Reflex curve (full line), and curve of discrimination (dotted line). Subject (CX). The part marked I, shows reaction time to the shock before the first conditioned reflex appeared.

The so-called conditioned reflex was developed on three other subjects, but a sufficient number of reactions were not obtained to construct their time-curves.

Subject (H.). An undergraduate student—60 trials. This subject was very much afraid of the shock. After 19 trials with the shock the first reaction to the positive stimulus appeared. The number of the trial, together with the time of the reaction to the positive stimulus and the accompanying remarks of the subject, are as follows:

Trial	Reaction-Time	Remarks
20th	0.153 sec.	"Nope! I missed it."
28th	0.499 "	"Missed it."
38th	0.111 "	"Oh pshaw, I didn't get anything."
45th	0.004 "	"I pulled before."
47th	0.117 "	"I pulled again."
51st	0.319 "	

After this sitting the subject said: "I am afraid all the time of the shock. I don't know whether I do you any good or not, jerking away like that." On the next sitting, after the first shock the subject could not keep his finger on the electrode. He always reacted before the hammer sounded.

Subject (Sh.). An undergraduate student. After 14 trials with the shock this subject reacted to the positive stimulus without the shock on the 15th trial (0.686 sec.), saying, "It didn't come that time." Again, on the 28th trial he reacted without the shock (0.821 sec.), saying, "I didn't get it." This subject evidently withdrew his finger, thinking that something was wrong.

Subject (Th.). A graduate student—70 trials. The number of the trial, together with the time of the reaction to the positive stimulus and the accompanying remarks of the subject, are as follows:

Trial	Reaction-Time	Remarks
18th	0.509 sec.	"Twice today I didn't feel any shock."
20th	0.655 "	"It didn't work."
25th	0.330 "	"Nothing doing, hey?" (Previous.)
27th	0.000 "	
30th	0.513 "	
33rd	0.270 "	
34th	0.121 "	
38th	0.1074 "	"You are fooling me now."
41st	0.382 "	
52nd	0.033 "	"Oh, I didn't get the shock." (Previous.)
54th	0.000 "	"I raised my hand too soon."
55th	0.429 "	
57th	0.558 "	
59th	0.625 "	
61st	0.000 "	
63rd	0.802 "	
66th	0.417 "	
67th	0.738 "	

"There were shocks at times and no shocks at other times. When I hear the 'click' (of the hammer) I expect a shock. When I didn't get the shock it was a peculiar sensation. I imagine the same as when I do get it." (This subject, thinking he had finished the experiment, was informed of the nature of the experiment and was then no longer used.)

DISCUSSION OF RESULTS

Our aim in measuring the time of the conditioned reflex was to get a further insight, if possible, into its nature. A comparison of the latent period of the conditioned reflex with that of other reflexes and reactions will be the first step in our further investigation. First let us consider the various attempts to measure the latent period of reflex actions, and then the reaction-time experiments in man.

Many experimenters have measured the time of several forms of reflex action. However, there is a great difference in their values, due no doubt, to a great extent, to the differences in method and technique employed. Thus, the method of Turck, who stimulated the tip of the frog's toe by dipping it into a weak acid and then measured the interval between the application of

the stimulus and the reaction of the limb, might give any time from 5 to 30 seconds. But, of course, the time lost during which the acid is soaking through the skin should be taken into consideration. On the other hand, the application of induction shocks to a nerve ending yields a much shorter time. Again, in the lower animals it has been found possible to measure the time during which the stimulus is elaborated in the spinal cord. This is done by subtracting the time of nerve conduction to and from the cord from the total reaction time.

The following measures have thus been obtained:[1]

Wundt—(Stimulating gastrocnemus muscle in frog)	0.008 sec.
(In crossed reflex)	0.012 "
Buchanan	0.014 to 0.012 "

These are termed the simplest reflex obtainable.

The following reflex movements of the turtle have been observed by G. Fano:[2]

Reaction of neck and head	0.060 sec.
" " foreleg	0.063 "
" " hindleg	0.060 "
" " hindleg (crossed reflex)	0.085 "
Raising lower jawbone	0.052 "

The lid reflex has been the object of considerable observation. The list below contains some of the experimenters and their respective reaction times obtained.

S. Exner[3]—(closing the lid after a light stimulus. Attached writing instrument to the lid.)	0.2168 sec.
Zwaardemaker and Lens[4]	0.088 sec.
Garten[5]—(Photographic registration)	0.061 to 0.132 sec.
S. Exner—(by stronger elect. stimulus)	0.0578 sec.
(" weaker " ")	0.0662 sec.

[1] Reported by Herrick; Intro. to Neurology, 1916, p. 98.

[2] G. Fano; Arch. Ital. de Biol., 39, 85, 1903. (Quoted by W. Nagel; Handbuch der Psysiol. des Menschen, 1909, IV, p. 263.

[3] Sigm. Exner, Pflügers Arch. f. d. ges. Physiol. 8, p. 526, 1874. (Quoted by Nagel.)

[4] H. Zwaardemaker und L. J. Lans, Zentralbl. f. Physiol. 1899, Nr. 13. (Quoted by Nagel.)

[5] S. Garten, Pflugers Arch. f. d. ges. Physiol., 71, p. 477, 1899. (Quoted by Nagel.)

Mayhew[6]—(by tactile stimulation of the skin of the cheek) .0.0420 sec.
Langendorff and C. Franck[7]—(by blowing on cornea).....0.07 to 0.182 sec.
(by blowing on cornea in rabbit) .....0.065 to 0.069 sec.

The knee-jerk or patellar reflex has often been investigated in man. The following table (given by Nagel) shows the time-values observed by various experimenters.[8]

Burckhardt (1877) .....0.040 sec.
Tschirjeff (1879) .....0.058 to 0.061 sec.
Gowers (1879) .....0.09 to 0.15 sec.
Brissand (1860) normals .....0.048 to 0.052 sec.
Brissand (1860) patients with increased excitability.....0.038 to 0.042 sec.
Waller (1880) .....0.03 to 0.04 sec.
Watteville (1882) .....0.030 sec.
Eulenberg (1882) .....0.016 to 0.038 sec.
Rosenheim (1884) .....0.025 to 0.10 sec.
Jendrassik (1894) .....0.039 sec.

Dodge and Benedict (1915) found a reflex-time of from 0.043 to 0.051 seconds for a knee-jerk.[9]

François Franck stimulated one leg of the frog and awaited the reaction of the other leg (crossed spinal reflex), and obtained a time of 0.022 seconds.[10]

Nagel observes that smooth muscles offer a greater resistance to contraction upon stimulation. Thus, he cites the following time-values, obtained on the pupillary reflex.[11]

Light thrown in eye—Listing.....0.4 sec.
F. Artljun & Donders .....0.492 sec.
M. vonVintschgan .....0.3 to 0.33 sec.

The Plethysmographic measure of the vasomotor reflex on man is 3 to 4 seconds. Thus there is a greater resistance to disturbance of the inner organs.

By increasing the induction-shock which stimulated the triceps muscle of the dog, François Franck[12] observed the following reflex times: 0.040 sec., 0.038 sec., 0.026 sec., 0.022 sec., thus show-

[6] D. P. Mayhew, Jr. of Exper. Med., 2, pp. 35-38, 1897.
[7] C. Franck, Ueber die zeirlichen Verhaltnisse des deflectorischen und willkurlichen lidschlusses. Inaug. Diss., Konigsberg, 1889. (Quoted by Nagel.)
[8] W. Nagel, Handbuch der Physiol. des Menschen, IV, 1909, p. 265.
[9] Dodge & Benedict, Carnegie Publ., 1915, Wash., D. C., pp. 36-46.
[10] See Nagel, *op. cit.*, p. 267.
[11] *Ibid.*
[12] Nagel, *op. cit.*, p. 268.

ing the influence of the strength of the stimulus upon the time of the reaction. Exner (cited above) noticed this in his observations upon the lid-reflex. W. Nagel[13] also stimulated the triceps femoris muscle in the frog and obtained a reflex-time of from 0.05 to 0.06 seconds. Wundt found that temperature effected the reflex-time in the frog.[14] Broca and Richet also found that it effected convulsion reflexes in mammals. By taking the temperature of the animals at different degrees they obtained the reflex convulsions, as follows:[15]

Temp. cent.	Time (seconds).
40	0.042
39	0.045
37	0.048
36	0.049
35	0.050
34	0.060
31.5	0.080
29	0.100

Thus, from all of the above time-values, it is safe to state that the latent period of any reflex involving voluntary muscles is easily less than one-tenth of a second.

We may next consider the reaction-time experiments. Wundt quotes the following:[16]

Muscular and Sensorial Reaction

	Muscular		Sensorial	
Experimenter		R. Time		R. Time
N. Lange	sound	127	sound	216
Balkin	"	121	"	235
L. Lange	"	124	"	230
N. Lange	elect. stim.	105	elect. stim.	213
L. Lange	light	172	light	290
G. Martius	"	182	"	291

Sound ..... 149—180—150—167—136—120—122—125
Light ..... 200—188—224—222—150—193—191—150
Electricity .... 182—154—201—201—133—117—146—

[13] *Ibid.*
[14] *Ibid.*
[15] *Ibid.*
[16] Wm. Wundt, Physiol. Psy., Fünfte Auflage, III, p. 414-430.

The above values are all more than one-tenth of a second in time. (The figures here, and in the following tables, as given by Wundt, represent "sigma," i. e., thousandths-seconds). As the reactions become more complex the time is naturally greater, as is shown below.

Discrimination

	R. Time		Experimenter
Between two stimuli	176-190	sigma[17]	(Friedrich).
" " "	224-235	"	(Tischer).
" " "	286-295	"	(Wundt).
" four "	293	"	(Friedrich).
" " "	287	"	(Tischer).
" " "	337	"	(Wundt).

Recognition

	R. Time		Experimenter
Numbers of one digit	324-308	sigma	(Friedrich).
" " " "	194-348	"	(Tischer).
" " " "	270-378	"	(Wundt).
" " six "	1079-1082	"	(Friedrich).
" " " "	887-1387	"	(Tischer).
" " " "	482-960	"	(Wundt).

Choice Reactions

			R. Time (average of 8 readings)		Experimenter
ONE hand reacting to	weak	stim.	312	sigma	(Tischer).
BOTH hands " "	stronger	"	317¼	"	(").
ONE hand " "	color	"	295-340	"	(Cattell & Berger).
BOTH hands " "	"	"	314-438	"	(" " ").
ONE hand " "	word	"	319-401	"	(" " ").
BOTH hands " "	"	"	348-437	"	(" " ").

Association-Time

Total reaction-time (including simple reaction-time)	1037	sigma	(R. B.)
" " " " " " "	896	"	(M. T.)
" " " " " " "	1154	"	(S. H.)
" " " " " " "	1009	"	(W.W.)

Where now does the "conditioned reflex" belong if we are to place it merely on the basis of its latent period? We are confronted at the outset with a difficulty. The series of values which we have, include many "previous" re actions giving zero reacti on-

[17] Wundt, *op. cit.*

times or measurements closely approaching zero. These are evidently not conditioned reflexes to the sound of the hammer, because they often take place before it raps. They are merely involuntary jerkings produced by the emotion of fear. If we were to add these in we would unjustifiably lower the average. On the other hand, there are a number of very long reactions, which are probably due to the fact that the subject is lagging through inattention or the lack of any definite task.

Under these circumstances, it would seem that the mode rather than the average would be more likely to give us the true time value of the latent period of the conditioned reflex.

TABLE I

Showing distribution of "conditioned reflexes," according to the reaction times measured, for each subject.

Subject.	0 to 50 sigma	51 100	101 150	151 200	201 250	251 300	301 350	351 400	401 450	451 500	501 550	551 600	601 650	651 700	701 750	751 800	801 850	TOTAL
N.	12	17	17	24	16	11	5	5	2	0	1	0	6	2	3	4	2	127
T.	34 (24=0)	16	16	7	4	2	5	5	2	1	3	1	1	3	1	0	0	101
C.	4	1	2	2	3	2	2	1	2	2	2	1	3	1	1	0	2	31
Cx.	2	5	8	47	37	4	3	2	0	0	0	0	0	1	2	0	0	111
H.	1	0	2	1	0	0	1	0	0	1	0	0	0	0	0	0	0	6
Sh.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
Th.	4	0	1	0	0	1	1	1	2	0	2	1	1	1	1	0	2	18
Total	57	39	46	81	60	20	17	14	8	4	8	3	11	9	8	4	7	396

The following table (I) gives us the results of all the subjects distributed in intervals of 50 sigma. The mode for all subjects lies between 151 and 200 sigma. Such a value is certainly not that of an ordinary reflex involving the voluntary musculature. It is comparable to the longer values obtained for muscular reactions, or to the shorter ones obtained for conscious discrimination reaction between two stimuli.

Only two of the subjects have well-defined modes. These are subjects (N.) and (Cx.). The average of N.'s 24 reactions at

the modal value is 170.4 sigma; the average of Cx.'s reactions at the modal value is 175.6 sigma.

Let us now see what values were obtained by an ordinary discrimination reaction with our subjects. The time of the conditioned reflex is on the whole a little shorter than those quoted by Wundt for discrimination reactions. Let us see, therefore, what times our subjects gave when they make a discrimination reaction to the same stimuli used in the development of the conditioned reflex—the bell and the hammer.

TABLE II[18]

Subject	0 to 0 sigma	51 100	100 150	151 200	201 250	251 300	301 350	351 400	401 450	451 500	501 550	551 600	Total
N	0	10	9	57	30	12	2	3	1	1	0	0	125
T	0	9	27	38	15	5	4	1	1	0	0	0	100
C	0	0	2	17	2	6	4	2	2	0	1	0	36
Cx	0	0	4	50	41	4	2	0	1	0	0	0	102
Total	0	19	42	162	88	27	12	6	5	1	1	0	363

(Showing distribution of the conscious discrimination reactions according to the reaction times measured,—in four subjects.)

Here again the modal value for all the subjects lies between 151 and 200 sigma. The two subjects N. and Cx., whose modal values were definite in the last experiment, have modal values lying between the same limits as formerly. The average of their modal values was formerly: N., 170.4 sigma, and Cx., 175.6 sigma; the corresponding averages are now: N., 160.4 sigma, and Cx., 176.0 sigma.

It would thus seem that, when judged by the objective standard of time, there is no difference between the conditioned reflex obtained in our experiments and an ordinary discrimination reaction.

Watson has hailed the conditioned reflex as a means of getting rid of an appeal to introspection in psychology. It seems really to be only a method of concealing an appeal to consciousness so

[18] In this table (as in table I) and hereafter, the term "sigma" is used. It merely designates thousandths seconds.

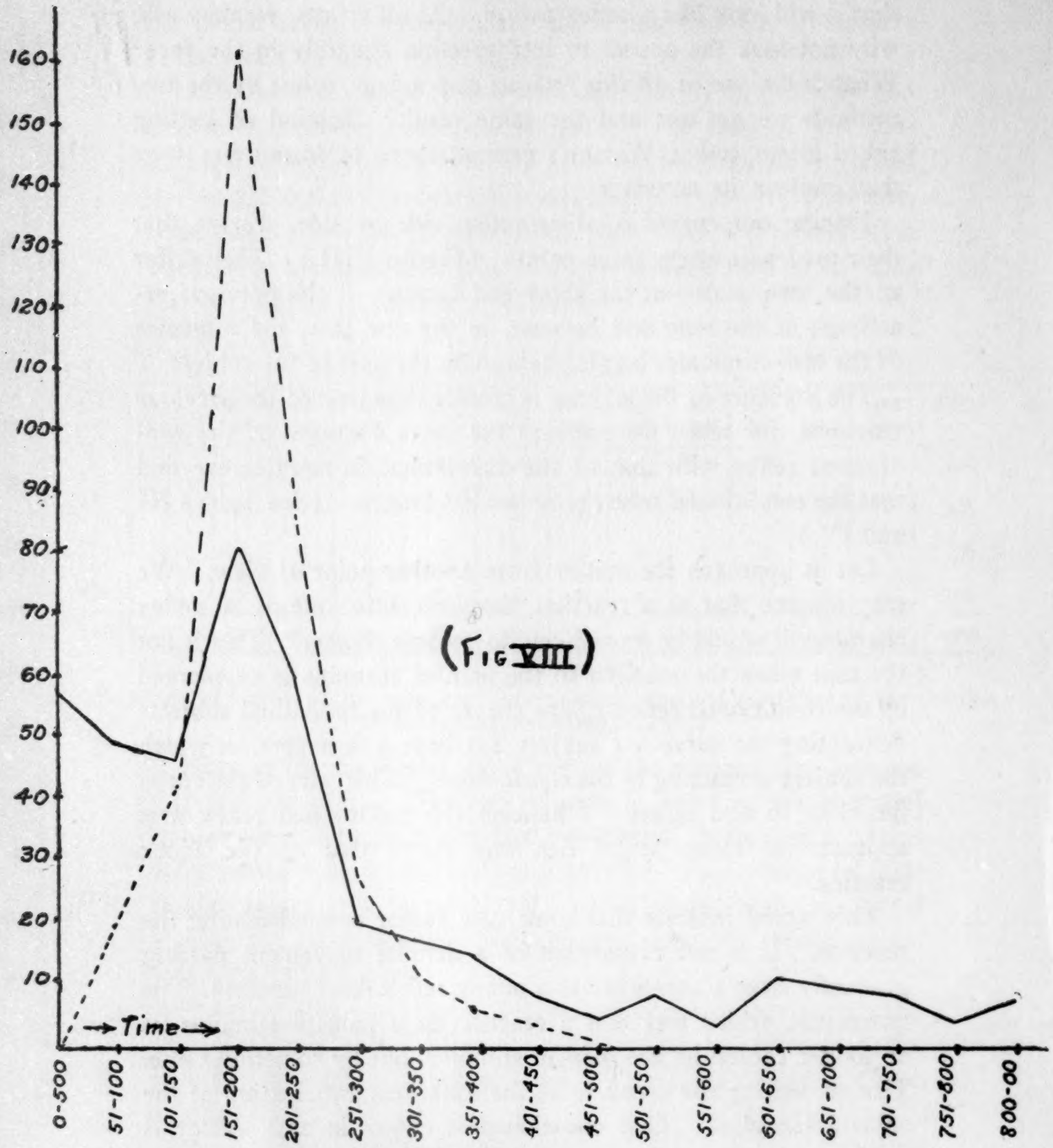
that it will look like a reflex action. At all events, we may ask, why not look the appeal to introspection squarely in the face? What is the use of all this tedious camouflage, when by the two methods we get one and the same result? Instead of getting rid of introspection, Watson's method seems to do nothing more than confirm its accuracy.

Placing our curves of distribution side by side, we see that their modes lie at the same point. (Figure VIII.) They differ at the two ends—at the short end because of the previous reactions; at the long end because, in the one case, the influence of the task eliminates lagging behind on the part of the subject.

The influence of the lagging is greater than that of the previous reactions, for when we compare the mean averages of the conditioned reflex with that of the discrimination reaction we find that the conditioned reflex is somewhat longer. (See Tables III and IV.)

Let us approach the matter from another point of view. We may assume that as a reaction develops into one of a reflex character it would be more likely to become shorter. This is not the case when the reaction to the painful stimulus is supplanted by the conditioned reflex. The curves of the individual subjects (excepting the curve for subject T.) have a first part, in which the subject is reacting to the shock alone. This part of the curve lies close to 100 sigma. Whenever the conditioned reflex first appears, its latent period lies way above that of the shock reaction.

This would indicate that some new factor is conditioning the reaction. It is not a question of a definite movement passing gradually from a non-reflex to a purely reflex determination. The movement, which was first a reaction to a painful stimulus, is no longer caused by the painful stimulus, but by something else. This something else seems to be the conscious anticipation of the painful stimulus. That consciousness enters in as a factor is confirmed by the observations of the subjects made during the experiments, and by their memory account of the experiment after they were through.



(Fig XIII)

Fig. 8. Curves of Distribution:
a. Conditional reflexes (full line).
b. Discrimination curve (dotted line).

TABLE III

Subject	No.	Average R. Time	Mean Average
N	127	237.8	
T	101	162.5	
Cx	111	201.4	224.8
C	31	385.0	
Th	18	364.0	
H	6	204.0	

(Showing the average reaction time to the conscious discrimination reactions for each subject; also the mean average time for all.)

TABLE IV.

Subject	No.	Average R. Time	Mean Average
N	125	196.0	
T	100	176.8	195.9
Cx	102	198.7	
C	36	241.0	

(Showing the average reaction time to the conscious discrimination reactions for each subject; also the mean average time for all.)

But, we may ask, how can you explain that the conditioned reflex is obtained with smooth muscle and glands that are not subject to voluntary control, e. g., the pupillary and salivary reflexes? One must be careful how such reflexes are interpreted. The act of attention, e. g., in multiplying figures, will cause the iris to dilate. That being the case, it is quite possible that "conditioned" dilatation of the pupil is conditioned by consciousness—by some such act, e. g., as the realization, "There is that hammer; if I don't get out of the way I shall get an awfully painful shock." Such conscious states might also occasion a salivary secretion in some subjects. If one were to measure the reflex time of dilatation of the pupil to darkness and its conditioned reflex time, it is very likely that the conditioned reflex would be longer.

But one may say the conditioned reflex may be obtained even

from animals. This does not exclude its being dependent on consciousness. In fact, if we find that the conditioned reflex is dependent on consciousness in man, it is very likely—though not certainly—dependent on something akin to consciousness in animals. Thus with all, and only with the strength of an analogical argument, one might say that organisms that have one eye and a nervous system similar to our own have also conscious sensations of light similar to our own.

The conditioned reflex will enable us perhaps to establish the limits of consciousness in the forms of animal life. Far from being a means of dispensing with consciousness, it seems more likely to be a criterion of its presence.

At all events, we may lay it down as a heuristic hypothesis that something akin to consciousness exists whenever a conditioned reflex may be established.

CONCLUSION AND SUMMARY.

The results of the foregoing experiments warrant the following conclusions, in brief:

1. That the reaction time of a conditioned reflex manifested by the action of voluntary muscles is much longer than ordinary reflexes involving striated musculature.

2. That the latent time of the so-called "conditioned reflex" approaches very closely the reaction time of conscious discrimination.

3. That observations and remarks of the different subjects made during the progress of the experiment reveal the fact that consciousness is a factor which plays an important role in the development of the conditioned reflex.

From these three propositions we are justified in pointing out a distinction between a genuine reflex action and the "conditioned reflex." A true reflex action takes place without the intervention of consciousness. Thus, the knee-jerk takes place before there is time for the stimulus to pass to the cortex, arouse a conscious sensation, and produce a reaction by an efferent path from the cortex to the *quadriceps femoris*. The stimulus, though it may

be perceived by the subject, need not be perceived in order that the knee-jerk may take place. The perception of the stimulus is in no sense a cause of the reaction, but something altogether subsidiary and non-essential.

In the "conditioned reflex" as developed in these experiments the reaction occurred first in response to a very painful stimulus. The latent period in this preparatory stage was about twice that of reflexes in striated muscles. When the "conditioned reflex" was finally developed its latent period was about four times that of ordinary reflexes. Furthermore, it depended upon an insight into the conditions of the experiment. It thus seems that the "conditioned reflex" is not a true reflex," but a reaction dependent upon a factor that we recognize and designate as conscious.

BIBLIOGRAPHY

Babkin, B. P. "Die Äussere Sekretion der Verdauungsdrüsen." Berlin, Springer, 1914.

Brunacci, B. "Sulla variazioni fisiologische della parotide nell'-uomo." Nota I, Arch. di Fisiol., 1910, 8, pp. 421-457. (Reported by K. S. Lashley.)

Brunacci, B., & De Sanctis, T. "Sulla funzione secretoria della parotide nell'uomo." Nota II," "Influenza inibitrice dell'-attivita psichita sullaquantita e qualita della saliva secreta." Arch. di Fisiol., 1914, XII, pp. 441-454. (Reported by K. S. Lashley.)

Colin, G. "Traité de physiologie comparée des animaux-domestiques." Paris, Baillere, 154-'56.

Cattell, J. M. "Reaction times and the Velocity of the Nervous Impulse." Nat. Acad. of Sci., VII., pp. 393-415.

Dewey, John. "The Reflex-Arc Concept in Psychology." Psychol. Rev., 1896, III, No. 4, p. 361.

Dodge, Raymond, & Benedict, F. G. "Psychological Effects of Alcohol. An experimental investigation of the effects of moderate doses of ethyl alcohol on a related group of neuro-muscular processes in man." Carnegie Publ., Washington, D. C., 1915, pp. 36-46.

Doutchef-Dezeuze, M. "L'image et les reflexes conditionnels dans les travaux de Pavlov." Paris, Alcan, 1914.

Eckhard, C. "Ueber die Eigenschaften des Sekretes der Mensch-

lichen Glandula Submaxillaris." Beitr. z. Anat. u. Physiol. 1863, III, pp. 39-50.

Exner, Sigm. Pflügers Arch. f. d. ges. Physiol., 8, p. 526. (Quoted from Nagel. op. cit.)

Fano, G. Arch. Ital. de Biol. 1903, 39-85. (Quoted from Nagel. op. cit.)

Franck, C. "Ueber die Zeitlichen Verhältnisse des reflectorischen und Willkurlichen Lidschlusses." Königsberg, 1889. (Quoted from Nagel. op. cit.)

Garten, S. Pflügers Arch. f. d. ges. Physiol. 1899. (See Nagel. op. cit.)

Gley, E., and Mendelssohn, M. "Quelques experiences sur le reflexe salivaire conditionnel chez l'homme." Compt. rend. Soc. de biol., Paris, 1915, LXXVIII, pp. 645-649.

Herrick, C. J. "An Introduction to Neurology." Phila., 1916, p. 66.

Herrick, C. J., & Coghill, G. E. "The Development of Reflex Mechanism in Amblystoma." Journ. Comp. Neur., XXV, pp. 65-85.

Kuss, G. "Notes sur la saliva parotidienne de homme." J. de L'anatomie, 1899, 35, pp. 246-253.

Lashley, K. S., "The Human Salivary Reflex and Its Use in Psychology. "Psy. Rev., XXIII, No. 6, pp. 446-464.

Lashley, K. S. "Reflex Secretion of the Human Parotid Gland." Jr. Exper. Psychol., Vol. I, No. 6, 1916, pp. 461-492.

Mayhew, D. P. "Jr. of Exper. Med.," II, 1897, pp. 35-38.

Mitscherlich, C. G. "Ueber den Speichel des Menschen." Poggendorff's' Annalen d. Phys. u. Chem'., 27, 1833, pp. 320-345.

Morgulis, S. "Pawlow's Theory of the Function of the Central Nervous System, and a Digest of some of the more recent Contributions to this subject from Pawlow's Laboratory." Jour. Animal Behavior, IV, pp. 362-379.

Nagel, W. "Handbuch der Physiol. des Menschen.," IV, p. 265 (1909.)

Oehl, E. "La saliva umana studiata colla siringazione dei condotti gliandolari." Pavia, Fusi, 1864. (Reported by S. K. Lashley.)

Ordenstein, L. "Ueber den Parotidenspeichel des Menchen." Beitr. z. Anat. u. Physiol. 1860, II, pp. 103-122.

Pawlow, J. "Ueber die Reflectoriche Hemmung," Arch. f. d. ges. Physiol., 1878, 16, pp. 272-292.

Pawlow, J. "Pawlow's Huxley Lecture." (Translated.) Lancet, 1916, CLXXI, p. 911.

Popielski, L. "Ueber die Gesetze der Speicheldrüsentätigkeit." Arch. f. d. ges. Physiol., 1909, 127, pp. 443-473.

Seldheim, A. P. St. Petersburg, 1904. (Reported by Babkin, op. cit.)

Tuczek, F. "Ueber die vom Menschen während des Kauens abgesonderten Speichelmengen." Zsch. f. Biol., 1876, 12, pp. 534-557.

Watson, J. B. "The Place of the Conditioned Reflex in Psychology." Psychol. Rev., 1916, XXIII, No. 2.

Wundt, Wm. "Grundriss der Psychologie." Leipzig, 1893, p. 421.

Wundt, Wm. "Physiol. Psy., Fünfte Auflage, III, pp. 414-430.

Zebrowski, E. V. "Zur Frage der secretorischen Funktion der Parotis beim Menschen." Arch. f. d. ges. Physiol. 1905, 110, pp. 105-173.

Zeljony, G. P. "Ein Hund ohne Grosshirnhemisphären." Verh. der Gesellsch. russ. Aerzte zu St. Petersberg. (Quoted from Babkin, op. cit.)

Zwaardemaker, H., und Lens, L. J. Zentralbl. f. Physiol., 1899. Nr. 13. (Reported by Nagel, op. cit.)